ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

Vol. XXXVII., No. 14.

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THE NEW YORK RAPID TRANSIT COMMISSION on April 1 adopted a two-track extension of its proposed route from the City Hall Park to the Battery, under Broadway. This extension of the proposed system was really a necessity to the financial success of the enterprise, and the only reason it was not included in the plan as originally adopted was that the board desired to be assured of the consent of a majority of property holders along lower Broadway before including it in the route. The board has taken measures to secure the consents of Elm St. property holders, and is apparently doing all in its power to hasten the letting of contracts.

A SUBWAY CONNECTING ALL CHICAGO RAILWAY stations is again under discussion. The proposed diameter of the subway is 14 ft., and it would be sunk about 35 ft. below the surface. It is proposed to carry passengers from one station to another by means of a trolley or compressed air system, in cars holding 25 persons each, and the uniform fare of 5 cts. is to be charged. A company is being organized with a capital of $10,000,000. The crossing under the Chicago River would be one of the most serious of the engineering difficulties to be encountered.

THE CONSTRUCTION OF A GRAND BOULEVARD and concourse, in the northern portion of New York city, is proposed by the Matthewson bill just passed by the New York Assembly. This suggested improvement is said to be the most extensive planned since the establishment of Central Park, and though the general plans are not yet fully matured the estimated final cost runs from $18,000,000 to $30,000,000. The bill was strongly opposed by the majority of the members from Kings county, or Brooklyn, as an undesirable measure, and one that even the Greater New York could not now afford.

THE AWARD OF THE JERSEY CITY WATER CONtract to the East Jersey Water Co. has been vetoed by the Mayor, Mr. Peter F. Wanser, on the ground that the specifications are indefinite as to the number of conduits required between the source of supply and the city. The bids under this call, which is the fifth or sixth in as many years, were received on Aug. 24, 1896, as published in Engineering News of Aug. 27, 1896. The Street and Water Board awarded the contract on Dec. 4, 1896, and the Board of Finance concurred in the award on Jan. 7, 1897. The veto is dated March 29, 1897, seven months after the bids were received. The contract was for 50,000,000 gallons of water per day, delivered so as to supply the city by gravity. But one supply conduit was to be provided, which we stated in our issue of Dec. 10, 1896, did not comply with the evident intent of the specifications. A temporary supply of water has been furnished Jersey City for nearly a year by the East Jersey Water Co., from the surplus of the Newark supply.

CAST-IRON PIPE AT $15.24 PER TON has just been bought by the city of Milwaukee for the ensuing year. This price will be paid for pipe 6 ins. and more in diameter, the successful bidder being the Addyston Pipe & Steel Co. For 4-in. pipe the city will pay the Chattanooga Foundry & Pipe Works $16.50 per ton, and for 3-in., the Rundle-Spence Manufacturing Co., of Milwaukee, will receive $16.65 per ton. A year ago the city of Milwaukee contracted for its year's supply of pipe with the Addyston Pipe & Steel Co. at $19.67 for the larger sizes and $21.67 for 3 and 4-in. pipe.

ANOTHER ENGINEERING COMMISSION for the new Cincinnati water-works is proposed by the local water commission in charge, which recently adopted a resolution providing for the submission of the final plans for the works to five engineers. The resolution provides that two of the engineers "should be men familiar with the treatment of the Ohio River or similar water." The chief engineer for the new works has not yet been selected.

DAMAGES FOR STREAM POLLUTION to the amount of $2,000 have been awarded a milkman in Newington, Conn., the defendant being the city of New Britain. The stream in question flows through the pasture of the plaintiff and receives the discharge from one or more of the sewers of the city. The case has been appealed to the State Supreme Court. It is stated that there are 14 other similar suits pending against the city.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was the collapse of the wooden trestle on the north end approach to the Ohio Connecting Ry. bridge crossing the Ohio River at Woods Run, on April 5, in the southern part of Allegheny, Pa. The road connects the Pan Handle and Fort Wayne divisions of the Pennsylvania Co. A freight train was crossing at the time, and the engine and 13 cars were precipitated to McClure Ave., 50 ft. below. The fireman was killed and the engineer injured so that he can hardly recover.

THE STEAM CHEST OF AN ENGINE BURST at the Lawrence Cement Co.'s mill at Eddyville, N. Y., on April 5, killing two men. The engine was a new one and was being tested at the time.

A STEAM BOILER EXPLODED at the works of the Hudson River Stone Supply Co., two miles north of New Hamburg, N. Y., on April 5, seriously injuring two men. ——Two men were killed by the explosion of a sawmill boiler at Valeen, Ind., on March 27.

AN EXPLOSION IN THE TUNNEL under Lake Michigan, opposite Chicago, which is being driven to furnish additional water supply, took place on March 30, killing two men and injuring five others. The explosion is supposed to have been due to natural gas which accumulated in the tunnel. The foreman stated that the tunnel had run into a pocket of black sand which exuded natural gas. "Every little while," said he, "we lifted a candle attached to a stick up into the roof of the tunnel and touched off the accumulated gas. I think it was a sudden exudation of this gas in greater quantity than usual that on being ignited caused the explosion." The foolhardiness of a foreman who would allow the "touching off" of gas in a tunnel is almost incredible.

A FLY-WHEEL BURST at the iron works of Lindsay & McCutcheon, Allegheny, Pa., on March 26. One man was severely injured. The cause was the usual one, the breaking of the governor belt, which allowed the engine to run away.——A fly-wheel of a threshing engine broke on a farm near Cornwall, Ont., on April 2, fatally injuring the owner of the farm and seriously wounding another man.

A TORNADO demolished the town of Chandler, Okla., on March 31, killing 20 people, injuring 170, of whom several will probably die. The town contained 1,500 inhabitants.

THE MISSISSIPPI FLOOD continues to increase, and waters are pouring through the crevasses, flooding a section of country several hundred square miles in extent. A crevasse in Tuinca County, Miss., in the northwestern corner of the State, is 2,000 ft. wide, and water flowing through it is covering all the country between the river and the main line of the Yazoo & Mississippi Valley Ry. A press dispatch from Greenville, Miss., dated April 6, says that fully 700 towns are under water and many are surrounded and cut off. The quantity of water in the flooded section is so vast that at least a month, it is estimated, will be required for all the water to run off. In Louisiana the levees are still unbroken, and much work is being done on them to increase their strength. At Memphis, Tenn., on April 6, the height of water was reported as stationary, but at St. Joseph, Mo., the Missouri River had risen 13 ins. in 24 hours. At Kansas City the river for two days had been rising at the rate of 1 ft. in 24 hours. The report of the Government Weather Bureau on April 4 would indicate that the height of the flood is likely to increase still further. It says:

> Heavy rains have occurred in the last 24 hours in the watersheds of the Arkansas, Cumberland & Tennessee, and along the Central Mississippi River; heavy rains or snows in the upper Missouri and light rains in the upper and lower Mississippi and Ohio Rivers.
>
> The Mississippi has risen from St. Paul to the mouth, except a fall of one-tenth at Keokuk, St. Louis and Vicksburg. It is above the danger line at St. Paul and La Crosse.

The levee broke four miles below Helena, Ark., on April 4, flooding the city and a great extent of surrounding country. Measures for the relief of the sufferers by the flood are being taken in all sections. Gov. M. Laurin, of Mississippi, has telegraphed the Secretary of War asking for an appropriation of $100,000 by Congress for the purpose of closing the crevasses and giving employment to the needy. A bill has passed the Senate authorizing the diversion to the relief of the sufferers the unexpended balance of the appropriations made from time to time for contingencies in connection with cholera and other epidemics. These balances amount to $450,000. Fargo, N. D., is threatened by a flood in the Red and Coulee Rivers. The west side of the town, which is the residence district, was overflooded on April 6 and a rise of another foot will put practically the whole city under water.

SURVEY OF THE U. S. FOREST RESERVES is provided for in an amendment to the Sundry Civil Appropriations bill, presented by Senator Pettigrew. This amendment appropriates $150,000, orders the Director of the Geological Survey to make a complete survey of all the lands withdrawn from the public domain, and it also provides new regulations for the conduct of all forest reservations, restoring to the public domain all areas better fitted for mining or agricultural purposes than for forestry. It prescribes rules for cutting and selling timber, for the ingress and egress of settlers and for prospecting and mining.

THE REGULATION OF BRIDGE SPANS, over the Ohio, Monongahela, Cumberland, Tennessee and Illinois rivers, proposed by the Dalzell bill now before Congress, is roundly condemned by the Engineers' Society of Western Pennsylvania. At a special meeting of the Society, called on March 30 to consider this proposed legislation, Mr. E. K. Morse pointed out that in many places the natural channel of the Ohio River, at stages favorable to navigation, is less than 750 ft. wide; and it was absurd, under such conditions, to demand a minimum span of 1,000 ft., or of 800 ft. over the Monongahela River. Mr. Morse also said that while the certified total loss through wrecks on bridge piers was only $750,000, from 1852 to date, the cost of erecting one double track railway bridge of 1,000-ft. span would be about $2,500,000. The total value of all the coal passing down the Ohio River averages less than $5,000,000 per year, as the bulk of the coal leaving Pittsburg is now carried by the railways. It was stated that the Dalzell bill would practically prohibit the building of railway bridges across these rivers and could not fail to be injurious to the commercial welfare of Pittsburg. The Society adopted a resolution instructing the President of the Society to appoint a committee of five to appear before the Congressional Committee on Inter-State and Foreign Commerce, and to endeavor to either defeat in toto H. R. Bill 9866, or to so modify it as to leave each case to be decided upon its merits by the War Department. The following committee was appointed: Messrs. E. K. Morse, Thomas H. Johnson, Gustave Kauffman, George S. Davison, W. T. Manning, and Emil Swenson, ex-officio.

JAPANESE BRIDGE MATERIAL, to the amount of 2,000 tons, is to be furnished by the Pencoyd Bridge Works, A. & P. Roberts, of Philadelphia, under a contract just awarded. The material will be in the form of 186 steel bridge spans of various lengths for use on the Imperial Japanese Railway. Bids for the work were received from a number of the largest manufacturers of structural steel in Europe.

A GIANT SEE-SAW is being built as one of the amusement features of the Tennessee Centennial Exposition, to be held at Nashville, Tenn., from May 1 to Nov. 1, 1897. This see-saw will be supported by a steel central tower, 30 ft. square at the base, and 75 ft. high to the upper pin. On this pin will be swung vertically a built steel beam, rectangular in section, thoroughly braced and 160 ft. long. From the meager plans presented, it would appear that this beam will be swung on its axis by means of two segments with which pinions driven by the operating machine engage. To the ends of the beam are suspended two cars capable of holding 25 persons each, and these cars can be lifted alternately to a point 150 ft. above the ground. Contracts have been let for the work to the following firms: The Shultz Brady Co., of Pittsburg, the steel construction; the Central Iron Works, of Michigan, the machinery; and the Triangle Electric Co., Cincinnati, the special motor to run all the machinery. All work is to be finished by May 1, and the company building the see-saw is organized with a capital of $25,000. A somewhat similar device was proposed for the Chicago Exposition, but it was rejected for the Ferris wheel.

THE SOUTH BUFFALO HARBOR AND SHIP CANAL Improvement Co. is seeking incorporation, with a capital of $10,000,000. As defined in the bill of incorporation, the purpose of the company is to deal in real estate in Erie county, New York; to build a ship canal in said county, and to operate this canal constructed in such manner as to connect Buffalo River with Lake Erie. The city of Buffalo may also contract with this company to relieve the Buffalo River from overflowing its banks and for making this river, or a part of it, navigable. Among the incorporators are named: Rufus M. Choate, Arthur W. Decker, James F. Curtiss and others.

STEEL WORK IN A MODERN POWER HOUSE.

By Harry R. Jones.*

The new electric power house of The Metropolitan Street R. R. Co., at Kansas City, Mo., offers a good example of modern steel power house construction. The dimensions of the house are: boiler room, 144 ft. long, 51 ft. wide; engine room, 144 ft. long, 63 ft. wide; the boiler and engine rooms both being 33 ft. 7 ins. from the top of foundation masonry to the under side of the bottom chords of the roof trusses. The unloading shed is 41 ft. long, 20 ft. wide.

The steel frame work construction, in a general way, consists of steel columns supporting steel roof trusses, all rigidly bound together with longitudinal struts and sway rods and transverse lateral bracing; the bracing for this plant being extra heavy to withstand the very high winds peculiar to that locality. The advantages of this construction are:

1. A rigid building capable of withstanding high winds and the vibrations of the engines, and of sustaining heavy loads.

2. A low first cost, as the walls of the building are only thin blanket walls.

3. A fireproof structure.

The roof covering for both boiler and engine rooms is slate laid upon wood sheathing with heavy builders' felt between, all supported by steel channel purlines.

In the engine room supported by the side columns are longitudinal plate girders supporting a 30-ton electric traveling crane.

In the boiler room, in front of and above the boilers, are located the steel coal hoppers, holding four days' reserve coal supply; the two hoppers directly in front of the stack are used as ash receivers. These hoppers are supported on two independent rows of latticed channel columns; the sides and ends of the hoppers forming the longitudinal and cross supporting girders respectively. Each hopper is supplied with a hinged spout containing a cut-off valve, the coal being fed into the boiler stokers by gravity.

*Contracting Engineer of the Variety Iron Works Co., Cleveland, O.

The thickness of the plates of which the hoppers are constructed is as follows: side plates, 5-16-in., bottom plates ¼-in., splice plates, ⅜-in. Each side of the hopper forms a girder, supporting the hoppers between the posts, and having angle flanges and stiffening angles. The thickness of the plates is excessive for the loads, even with a factor of safety of five, and allows a large margin for possible corrosion.

The unloading shed is of light steel frame construction, covered on the roof, one side, and the gable ends with corrugated iron. This shed is used as a protection during the unloading of the coal from the cars.

The economical handling of the fuel supply and of the ashes is deserving of special attention. From the car in the unloading shed the coal is shoveled by hand into the receiving hoppers; then a conveyor carries it under the boiler room floor to the end elevator, thence to the coal hoppers overhead, where a horizontal conveyor distributes it throughout their length. From the hoppers it is fed by gravity into the stoker hoppers. The vertical conveyor also carries the ashes from the ash pits and delivers them into the two center hoppers located in front of the stack, from which they are drawn by gravity directly into the receiving cars in the unloading shed. By this arrangement the fuel and the refuse ashes are handled only once.

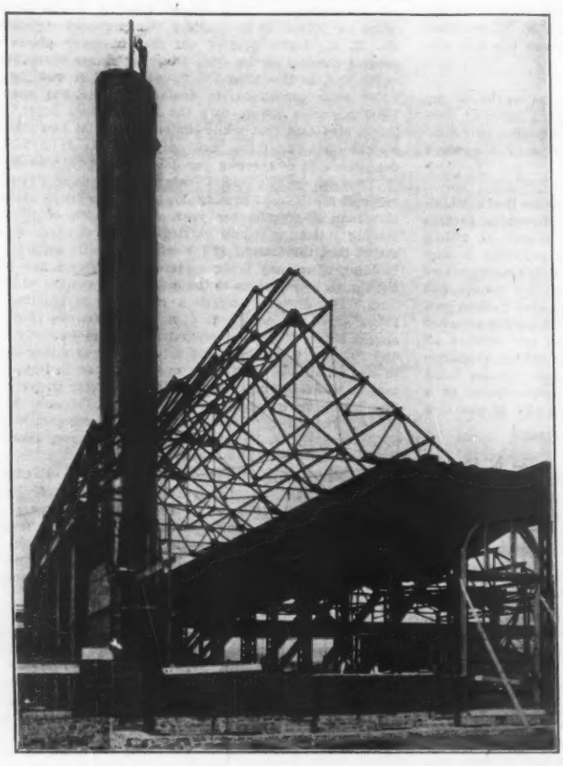
The conveyor-driving machinery is located in the boiler room roof trusses, the trusses being designed especially heavy to carry this machinery, the conveyor, and its load. The floors of the engine room and boiler room are supported on steel beams.

The stack for this plant is a self-supporting steel one, 175 ft. high above foundations by 10 ft. 6 ins. diameter of shell, with a clear flue of 8 ft. 4 ins. inside of the brick lining. The stack is located between the boilers in the center of the boiler room. The economy of a steel stack, giving better draft and a lower first cost compared with a brick one of the same capacity, is manifest, the cost of maintenance being but a trifle.

The switch board is supported by a steel gallery in the engine room. This gallery and the stairs leading thereto have an ornamental iron railing, which adds to the appearance of the engine room. The entire plant presents a pleasing appearance from an architectural view, as seen by the cut.

The material used throughout was medium steel of about 62,000 lbs. tensile strength, with an elongation of 20% in 8 ins.; the specifications for material and workmanship calling for first-class work.

The entire metal work of this plant, including the structural steel, coal hoppers, and steel stack was designed and furnished by The Variety Iron Works Co., of Cleveland, Ohio, who have also recently completed several power plants of similar design. The work was under the supervision of Mr. D. W. Dozier, Chief Engineer, and Mr. Walter C. Root, Architect, of the Metropolitan Street R. R. Co.



View Showing Coal Hoppers.

View Showing Walls Nearly Completed.

BOILER HOUSE WITH STEEL FRAMEWORK.

Built by the Variety Iron Works Co., Cleveland for the Metropolitan Street R. R. Co., Kansas City, Mo.

THE WELLINGTON SERIES ENGINE—AN ENTIRELY NEW SYSTEM OF DEVELOPING POWER FROM HEAT.

Many of our readers will recall that in our obituary notice of the late A. M. Wellington, M. Am. Soc. C. E., formerly one of the editors of this journal (Eng. News, May 23, 1895), mention was made of the fact that the last years of his life were devoted to the development of a new form of heat engine, radically different from anything ever invented and promising to effect remarkable results in the transformation of heat into power.

Work upon this invention had occupied a large part of Mr. Wellington's time for some years prior to his fatal illness; and experimental work upon it continued almost up to the very week of his death. Since that time the patents on the invention, which were then pending in the United States and all principal foreign countries, have been issued; and while it was his intention to publish nothing concerning his invention until it was actually constructed and put in practical operation, it now seems best, in view of the great scientific interest which attaches to the invention, as well as its promise of eventual commercial importance, to make public a description of its principal features.

At the outset, it may be said that the Wellington series engine is an apparatus designed to convert

heat into power with a greater efficiency than is obtained in the best existing forms of steam engine. For example, the very best existing steam engines convert into mechanical work some 10% to 12% of the total heat generated by the fuel burned in the boiler furnace. A thermodynamic analysis of the Wellington engine shows that it should effect this conversion with much greater efficiency; and if made commercially successful should convert into power from 25% to 40% of the total amount of heat generated by the fuel which it consumes.

In general it may be described as an arrangement of several ordinary steam engines in a series, with their respective boilers and condensers arranged in such a manner that the wastes of one engine are utilized in the next. In other words, the heat discharged from one boiler is utilized in the next one of the series, and the heat accumulated by passing the cooling fluid through the several condensers in series is also utilized to economize the fuel consumption.

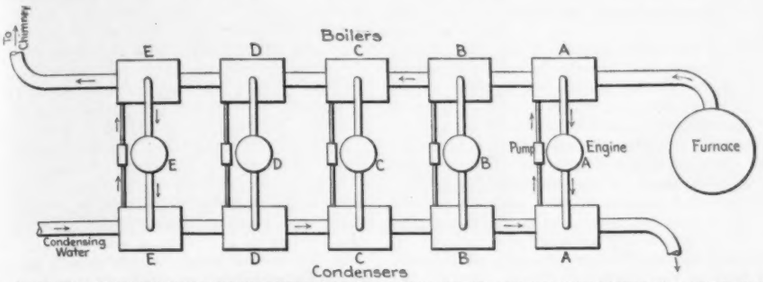


FIG. 1.—DIAGRAM ILLUSTRATING FIRST STEPS IN THE DEVELOPMENT OF THE WELLINGTON SERIES ENGINE.

The general principle of operation of the engine is illustrated in the diagram plan, Fig. 1. Here A, B, C, D, E, are a row of ordinary steam engines, each supplied with steam from a boiler on one side of it and exhausting into a surface-condenser on the other side. The liquid which accumulates in the surface-condenser is pumped back into the boiler by a pump attached to the engine.

The boiler, engine and condenser, marked B, are exact duplicates of those marked A, and the same is true of the set marked C, the set marked D, and the set marked E. Evidently now if a furnace were attached to each boiler and a suitable supply of cooling water were piped to each condenser, we would have five complete working steam power plants, each independent of the other.

But now suppose that instead of burning fuel under each boiler we place a single furnace at the right hand end of the row, and pass the hot gases from it first through the tubes of boiler A, then through the tubes of boiler B, then through boilers C, D and E. Also suppose that we connect the several condensers so that the cooling water flows first through condenser E, then through D, and so on till it finally leaves condenser A. It is evident that each separate set, consisting of boiler, engine and condenser, will still be operative, and that we may expect a greater total output of power from a given consumption of fuel and condensing water than before, for by the successive passes the heat will be pretty thoroughly extracted from the furnace gases by the boilers, and likewise the condensing water will be heated up to about the point at which it is no longer efficient by the time it leaves the last condenser.

Of course, with the arrangement above described boilers A and B would make a surplus of steam, while boilers D and E would make very little On the other hand, the condenser E would be very efficient; condenser D would be somewhat less efficient, and so on until condenser A would probably have difficulty in maintaining a proper vacuum.

If the above simple discussion is plain to the reader, he will have no difficulty in understanding the Wellington engine. In this engine, as illustrated by diagram in Fig. 2, we have a "circulating fluid" which takes the place of the hot gases from the furnace and the cold condensing water in the mechanism just described. This circulating fluid may be either a liquid or a gas, but for the present purposes, let us consider it a liquid, which fills all of the piping in the entire circuit from the heater at the left hand end, through the tubes of the several boilers from A to E, then through the tubes of the cooler, then through the tubes of the several condensers from E to A, and finally into the heater again. The liquid is caused to circulate by any suitable form of pump, as will be more fully described later on. It will be seen at once that by the use of a continuous circulating fluid, all the heat which is accumulated as the fluid passes through the several condensers is not lost as in the example first cited, but is directly utilized and lessens by just so much the fuel consumption in the heater.

Now, finally, to avoid the inequality of operation noted in the first example, and to make every engine, boiler, and condenser perform the same amount of work with the same efficiency as every other one in the series, a uniform "heat interval" is adopted for each boiler and for each condenser. By the term "heat interval" is meant the number of degrees difference of temperature between the water in any boiler or condenser and the circulating fluid which is imparting heat to the water in the boiler, or absorbing heat from it in the condenser.

To make the idea still plainer, let us suppose that the circulating fluid leaves the heater at a temperature of 500° F., and leaves boiler E on its way to the cooler at a temperature of 220° F. Then its temperature will be decreased 56° in passing through each boiler. Suppose that in the cooler its temperature is reduced to 50° F. Next in the condenser E it will receive as much heat as was imparted to boiler E less the amount converted into work by engine E and the loss of heat by external radiation from the boiler and engine E. Suppose this total to be 15%. Then the gain of temperature in each condenser as the fluid passes along will be 85% of 56° or 47.6° in each condenser. We have marked these various temperatures upon the diagram, Fig. 2.

Suppose also that the pressure of the steam in each boiler is that due to a temperature 10° less than that of the circulating fluid leaving that boiler, and that a similar difference of temperature exists in each condenser between the temperature of its contents and the temperature of the circulating fluid leaving it. Then the temperature in boiler A will be 434° and in condenser A, 278°. Then the absolute pressure of steam in boiler A will be 355 lbs. and there will be a back pressure in condenser A of 48 lbs. In a similar way we find that boiler B will work at a pressure of 192 lbs. and a back pressure of 21 lbs. will exist in condenser B. In boiler E a pressure of 14 lbs. absolute will exist and the condenser E will have a vacuum of 28 ins.

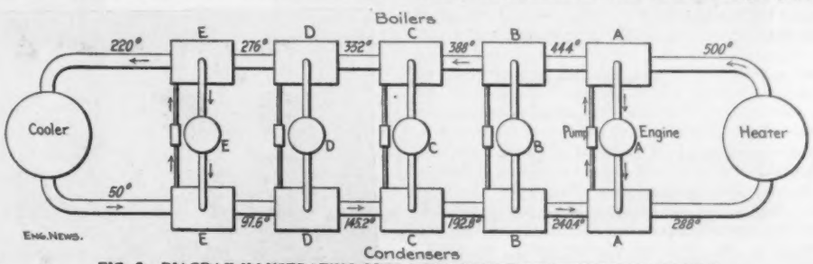


FIG. 2. -DIAGRAM ILLUSTRATING OPERATION OF WELLINGTON SERIES ENGINE.

It will be evident that under these conditions, with water and its vapor used as the working substance in each engine, as we have assumed, the engines toward the right will do a much larger amount of work than those toward the left. But now suppose that instead of using water as the working substance in each engine, we use it for one or two engines only, say for engines A and B, and for the engines C, D and E we adopt a working substance which will evaporate at a lower temperature, so as to give approximately the same amount of work with the same drop in temperature that occurs in boilers A and B. The progress in refrigerating machinery has given us quite a list of substances which are now extensively used under conditions similar to those which would obtain here. We may mention, for example, ammonia and carbon-dioxide. Other liquids more volatile than water which have been suggested as working substances, and some of which have been used in experimental engines or refrigerating machinery, are alcohol, ether, chloroform, carbon bisulphide; carbon tetrachloride, and aceton (C_3 H_6 O). Mr. Wellington also proposed and experimented with the distillates of petroleum as working substitutes. It is well known that by the process of distillation at different temperatures there can be obtained from crude petroleum a series of distillates having boiling points covering a wide range, and within this range a distillate can be obtained having a boiling point wherever desired.

On the other hand, it is not essential that different working substances be used in the different engines: on the contrary, the advantages of simplicity due to the use of steam alone as the working substance may cause that to be adopted except in cases where so large an amount of power is to be generated as to make the greater economy due to the use of different working substances an important object.

It will be seen, for example, that with a series of five engines, as shown in Fig. 1, we could use water as the working substance in all, and by varying the amounts of heating surface in the different boilers and condensers, we could secure the same output of work from each one of the five engines. More in detail, we would give boiler A a small heatng surface, boiler B a greater amount, and so on till boiler E would have the most of all. On the other side of the circuit, condenser E would have the least surface and condenser A the most.

Before discussing the design of the engine farther, a few words should be said regarding its efficiency, and by efficiency we mean what percentage of the heat supplied to it should it convert into work. It will be readily seen that the formula for its efficiency can be stated as follows:

Efficiency = (Heat supplied in heater — heat lost in cooler and by radiation) ÷ heat supplied in heater.

It will be seen that the numerator of the above fraction represents the heat that is converted into work.

But the efficiency of the apparatus can be determined in another manner. Careful analysis, which space does not permit us to repeat here, shows that the Carnot formula is true for this as for all other heat engines and that its limit of efficiency is measured by the total range of temperature between the point at which heat is supplied and that at which it is voided.

In the ordinary steam engine, as is well known, the efficiency increases as we raise the steam pressure and thus make the range between the temperature of the steam entering the cylinder and that leaving it greater. So in the Wellington series

engine, the limit of efficiency depends still on the range of temperature. Now, with the use of different working substances in the different engines, it becomes possible to greatly extend the thermodynamic range and thus to increase the possible efficiency of the engine. In fact it is claimed for this engine that it affords a means of converting heat into work by the force of vapor expansion under a greater range of temperature than is possible with any other form of motor.

Before proceeding further with the discussion of efficiency we may turn to an examination of the details of construction and operation of the Wellington series engine. Taking up first the engines proper, it is evident that these may be any ordinary single-cylinder engines with a cut-off adjusted to give maximum economy. Regulation of speed would be by a throttling governor, probably, as other methods of regulation make the attachment of a governor to the separate engines only necessary to provide for sudden changes of load. The mechanical arrangement of the engines and the grouping or arrangement of the different sets in a series will of course depend upon the particular work for which the engine is designed. It may be pointed out here, however, that it will probably be found advantageous to make the several engines exact duplicates of each other, both for economy in manufacture and convenience of repair. It will be also advisable to so mount the several engines that any one engine can be disconnected from the rest for adjustment or repair. With this done, it will be simply necessary to close the valves on the pipes leading to boiler and condenser to stop any engine of the series. This can be done, moreover, without interfering at all with the other engines of the series. They will in fact work with somewhat more power and better economy than before, on account of the fact that no demands are made on the circulating fluid by the boiler and condenser of this engine, and the power and economy of the apparatus as a whole will be only slightly decreased.

The pump by which the liquid which accumulates in the condenser is forced back in the boiler may also be any simple form of force pump, requiring only to be so set that the liquid from the condenser will flow to it by gravity.

Turning now to the boilers and condensers to be used with this new form of engine, it is apparent at once that an entirely different structure from the ordinary boiler is required, and upon the successful design of such a structure the practical success of the invention as a whole is doubtless dependent. If a series engine were to be built with boilers of the ordinary externally fired type, their bulk and the loss of heat by radiation would alone be sufficient to make the apparatus impracticable and inefficient as a heat engine.

Fortunately, under the conditions in which the series engine operates, the problem of reducing bulk and increasing efficiency in the boilers and condensers is greatly facilitated. To make this entirely clear, we may give an idea of the functions of boilers and condensers somewhat different from that ordinarily held. Any steam boiler, of any type, kind or size, may be considered as so many square feet of thin metallic heating surface, on the one side of which are the hot gases of the fire, and on the other side the water to be evaporated. Now, the amount of heat transmitted through a square foot of heating surface in the ordinary boiler is limited almost solely by its ability to take up the heat from the fire on the one side. The metal of the plate itself has a rate of heat conductivity so great that it is almost no obstacle to the transfer of the heat. In other words, at the ordinary rate of heat transmission in steam boilers the heating surface acts just as efficiently as it would were it as thin as paper. Again, the water side of the plate in a steam boiler can transmit heat many times as fast as the fire side. This is really a matter of common knowledge. The blacksmith pulls a red hot iron from the forge and holds it in the air for several minutes before it ceases to glow. But if he plunges it into water the glow will disappear in as many seconds. Equally simple experiments show that in any boiler the temperature on the fire side of the plate is practically the same as that of the water on the other side. Fill a vessel with cold water at a temperature of 50° or less and heat it by a flame from a lamp or a gas jet. The cold surface of the vessel will condense a visible dew from the gas which is passing over it at a temperature of over 1,000°.

We cite these examples merely to make plain the scientific fact above noted, that the limit to the capacity of our present boiler heating surface is its ability to absorb heat. But in the boilers of the Wellington series engine the heating surface is no longer acted upon by a hot gas, but by a hot liquid, which can convey heat to the surface many times as rapidly as hot gases from a fire. Thus a square foot of heating surface in the Wellington boilers will transmit many times as much heat as in boilers of the ordinary type.

There are two other factors which are always present to hinder heat transfer in ordinary boilers, but are absent in the Wellington boilers. In an ordinary boiler, scale accumulates on the water side of the heating surface and is frequently an important factor in decreasing the amount of heat transmitted. More important still, soot and ash accumulate constantly on the fire side of the heating surface and almost always forms a serious hindrance to heat transfer. But in the Wellington boilers there is nothing to cause any deposit on the heating surface, either of scale on the one side or soot on the other.

Again, the factor of circulation is a potent one to affect the rate of heat transfer in steam boilers. Both gases and liquids are poor conductors of heat, and in order that they may transmit their heat to a plate they must be moved over it, so that the cooled particles of the fluid are at once replaced by heated ones. In the Wellington engine this circulation is a positive mechanical one, and it offers an admirable means of regulating the action of the boilers.

It will be apparent from the above that in point of bulk the boiler belonging to each separate engine in a Wellington series set is not to be likened to an ordinary boiler at all. It would be much more nearly like a surface condenser, though much smaller still, and every engineer knows that a surface condenser for even an engine of large power is by no means a very bulky apparatus.

It seems likely to the present writer that a successful series engine could be built following the general lines of ordinary surface condenser practice for the design of the boilers and condensers. But while such an engine might be a success experimentally, it might on the other hand be too bulky to be a commercial success.

Mr. Wellington in his study of this feature of his invention became convinced that it was possible to construct boilers for his engine which should have an enormous power in a small space. Practically the entire experimental work which was done upon the invention was in this field, and that it was in some degree successful will be evident from the fact that a 2-HP. steam engine was actually operated at full load by steam from a boiler with a bulk of less than 1-10 of a cubic foot.

These remarkable experiments are alone well worthy of permanent record as a bold departure in mechanical engineering and in a direction which may yield important results.

The boilers with which Mr. Wellington experimented were of two classes. In his first work he followed the design of the ordinary multitubular boiler, except that the dimensions adopted transcended anything ever tried with steam boilers. He adopted as a standard copper tubes only ¼-in. in diameter and spaced them as closely together in the tube-sheets as was mechanically possible. The first boiler built was only 9 ins. long and 5 ins. in diameter, giving a volume of only one-tenth of a cubic foot. Yet in an actual test it developed 1½-HP. when evaporating a petroleum distillate with a boiling point of 80° F. and heated by a stream of water at 212° Fahr.

Of the second boiler of this type a photograph is shown herewith, the tubes and tube plates being removed from the boiler shell. It will be seen that the flange of the tube-sheet at the left is conical, while that on the right is cylindrical. To assemble the boiler, the parts shown in the photograph are forced into the shell (a piece of brass or copper tubing). The end plates are then put on and conical collars bear against the flanges of the tube plates, forming a steam-tight joint. As a matter of interest we give the detail dimensions of both this boiler and the first or "teapot" boiler, as it was dubbed, copied from Mr. Wellington's own notes of his experiments:

Inside dimensions.	First or "Teapot" Boiler.	Boiler shown in Fig. 3.
Length, ins.	9½	21.
Diameter, ins.	4⅜	10.
No. tubes	192 + 5 steam	903.
Length tubing, ft.	154	1,580¼
Tube surface, sq. ft.	10.08	103.3
Total volume, cu. ft.	0.103	0.956
Of which the tubes make, cu. ft.	0.0504 = 49%	0.513 = 54%.
Of which the steam and water make	0.0526 = 51%.	0.443 = 46%.
Volume of cylinder of engine filled (600 times per minute), cu. ft.	0.0179	
Weight of contents (water for working substance)	2.37 lbs.	20.8 lbs.
Horse power with 35° to 40° transmission interval	1.43 HP. actual	15 HP. estimated
Horse power, with 5-fold transmission interval = 175° to 200° F.	7.15 HP. estimated	75 " "
Horse power, per cu. ft. of total volume	14 HP. (actual)	14.3 " "
Horse power, per cu. ft. of total volume with 5-fold transmission int.	70.0 HP. estimated	71.5 " "
Spacing of tubes, c. to c., ins.	0.33	0.30

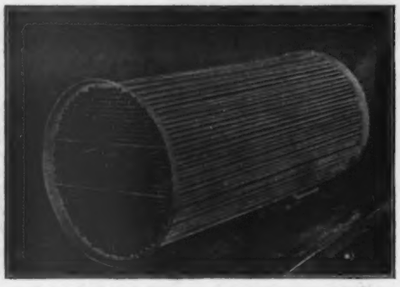


Fig. 3.—Photograph of Multitubular Boiler for Wellington Series Engine (Tubes removed from Shell).

Dimensions	10 × 21 ins.
No. tubes (¼-in. diameter)	903
Total volume	0.956 cu. ft.
Weight of water contained	20.8 lbs.
Heating surface	103.3 sq. ft.
Weight complete	47.25 lbs.

The larger of these two boilers was also at a later date tested when supplying steam to an ordinary engine. We quote again from Mr. Wellington's notes, written just after this boiler had been completed, and giving some interesting particulars of experiments with the smaller of the two boilers, which will answer some queries respecting the practical aspect of steam generation under these novel conditions which will arise in the minds of many engineers:

This boiler and corresponding condenser is now (Feb. 10, 1894,) being erected for test and to run a 40-HP. shop engine, requiring at that rate a transmission interval of about 112° F. and about ½ lb. water in boiler per HP. The regulation cylindrical tubular 40-HP. boiler is about 170 cu. ft. in volume for boiler only, weighs upwards of 6,000 lbs., empty, and contains some 5,000 lbs. of water. Despite its much larger transmission interval (say 800° F., mean of all heat transmitted), it needs six times as much surface, or 600 sq. ft., because of the lower efficiency of air as a heating medium and the method of applying heat.

It will be observed that the cylinder volume of the "teapot boiler" was just 30% of the total interspace of the volume. The average cut-off was over one-third, and speed 300 revs., or 600 strokes per minute, so that steam to fill over 10% of the boiler interspace was drawn off ten times per second. The steam space only was with boiler 4-5 full, about 11.2% of the boiler volume, so that, practically speaking, the entire steam contents of the boiler were drawn off at every stroke, 10 times per second. Notwithstanding this extremely rapid and intermittent withdrawal of steam, there was at no time the faintest shadow of flickering either in the steam gage or the water gage, nor was there when the engine was run at a much slower rate, from some 60 revolutions up. Had it been attempted to produce the same quantity of steam from this same boiler with heat applied chiefly at the bottom, beyond all reasonable doubt the first stroke would have carried the entire liquid in the boiler or most of it into the steam pipe and cylinder. With the greatest heat at the top, however, only 0.006 cu. ins. of water needed to flash into steam to fill the cylinder for a stroke, which occurs instantly on demand from the surface, producing no motion of the liquid and no sensible fluctuation of steam pressure.

The fact that a boiler has actually been built and worked which generated 40 HP. with a weight

and bulk only one two-hundredth as great as the ordinary stationary boiler of that power is certainly one calculated to command the attention of engineers.

Very soon after this larger boiler was built, however, Mr. Wellington hit upon an entirely new plan of boiler construction by which he hoped to go even farther in the direction above noted in the reduction of weight and bulk for a given power, and at the same time to make a boiler which would be constructed at a far less cost than the tubular boiler. Space forbids us to do little more than describe the general principles of this boiler.

It consisted of a series of copper plates about 15 ins. in diameter, which are covered with peculiar corrugations or channels. These were joined together in pairs, the edges of each pair being brazed so that the two plates facing each other formed a closed chamber. A number of these pairs are placed in a tubular case and are so connected to pipes at the top and bottom that fluid can circulate through them. Pipes are also connected to the case in which these sections are placed, so that the circulating fluid which heats the working substance will pass through the narrow channels which are left between each pair of plates. In this manner an enormous amount of heating surface is obtained in a very small space. In fact, this type of boiler is far superior even to the tubular boiler shown in Fig. 2 in this respect.

So promising did this invention appear as a means of solving the problem of the transfer of heat in small space with a small temperature interval, that a great part of the work done in the development of Mr. Wellington's invention was devoted to the design and perfection of this plate boiler. A boiler was actually built made up of 26 sections, with plates 16 ins. in diameter and containing 208 sq. feet of heating surface, and a great amount of experimenta data were accumulated respecting the best methods of manufacture of boilers of this type.

Of course, in the development of this invention a great variety of details were worked over and developed; but space does not permit their description here. Our readers who desire to study the invention in more detail are advised to secure copies of U. S. patents Nos 549,981, 549,982 and 549,983, issued Nov. 19, 1895, which cover the invention and various modifications in detail. These patent specifications form really an elaborate treatise on the series engine, including an extended discussion of its theory.

An interesting feature of these patents is that they were so far outside the beaten track of inventions that they were allowed by the patent office with practically no references. The total number of claims in the three patents is 330.

Other important questions respecting this invention and its practical applications, we have discussed in our editorial columns.

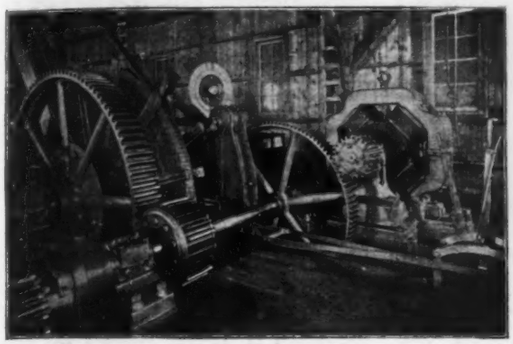


FIG. 1.—OVERBALANCED ELECTRIC HOIST OF 125 HP., FREE SILVER MINE, ASPEN, COLO.

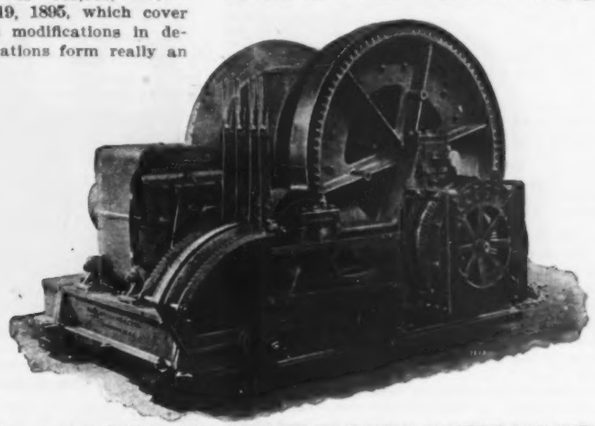


FIG. 4.—LIDGERWOOD HOIST OPERATED BY GENERAL ELECTRIC 2,000 MOTOR, PLEASANT VALLEY COAL CO., CASTLE GATE, UTAH.

ELECTRIC HOISTS IN DEEP MINES.

The application of the electric motor to hoisting work in mines has made great progress during the past few years. The following particulars concerning recent installations have been furnished us by the General Electric Co.:

One of the good features of electric hoists is that they may be located in relation to the incline or shaft exactly where they can be operated with the greatest advantage consistent with convenience of position and without any of the pipe connections which are necessary with the air or the steam hoist. In responsiveness to the movement of the starting lever, the electric motor is instantaneous. There is no short interval of hesitation as in the steam hoist. The speed is constant and only the requisite power required to handle the load is consumed, while the general cost of operation is claimed to be less than with compressed air or steam hoists.

Among some important electric hoisting plants at mines are the following: At the Free Silver Mine at Aspen, Colorado, is an electrical hoist, rated at 125 HP., but capable of giving 200 HP. This is believed to be the largest electrical hoist in the world. It has a double reel flat rope over a balanced hoist, built after the designs of Mr. D. W. Brunton, Manager of the Free Silver Mining Co., and also of the Cowenhoven Tunnel, Della S., Alta Argent and Johnson Mines.

The electrical equipment consists of a General Electric Company's 100 K-W. mutlipolar motor, with a speed of 550 revolutions per minute, and a smaller motor of similar type of 60 K-W. capacity and a speed of 475 revolutions. This smaller motor is ordinarily used to run an air compressor and winch for pulling pumps, but in case the main hoist-motor is called upon for heavier work than usual, the smaller one can be thrown in gear with it.

The hoist being counterbalanced, the load on the motors is reduced to about one third of that which would be thrown on a plain hoist of the same capacity. The radius of the arms of the reels is 5 ft., each reel carrying 1,500 ft. of rope 4 ins. wide and ⅝-in. thick. The hoist is provided with a car and cage, and the loaded car and cage weigh about 5,000 lbs. As in sinking the mine it cannot be timbered entirely to the bottom, and the cage cannot go below the timbering, a bucket is hung below the cage. This is 35 ins. high and about 28 ins. in diameter. It weighs 400 lbs., and holds 12¾ cu. ft. of water weighing 800 lbs., or rock weighing 2,000 lbs. To relieve the shaft from a sudden inflow of water, this hoist is provided with a bailer, which is used as an adjunct to the pumps. This is 4 ft 2 ins. by 3 ft. 2 ins. by 8 ft. 4 ins. and weighs empty 1,950 lbs. and filled 8,880 lbs. The counterweight used with the cage and bucket is 2,450 lbs., with the cage and car 2,675 lbs. With the bailer these two weights are used making a total counterweight of 5,125 lbs. The maximum hoisting speed with the cage and ore, and using the small pinion on the motor, is about 600 ft. per minute; with the bailer and using the larger pinion about 1,000 ft. per minute. The voltage used is 525 volts, and the current is taken from the central station at Aspen.

Last summer an interesting test was made with this hoist when using it for bailing. At that time the mine

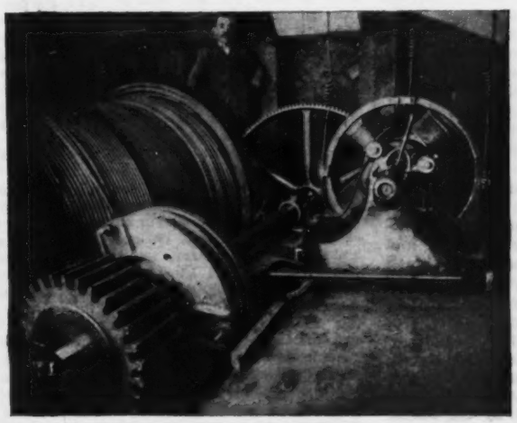


FIG 2.—ELECTRIC HOIST AT ALTA ARGENT MINE, ASPEN, COLO.

FIG. 3.—VIEW OF HEAD OF INCLINE FOR ORE CARS AT ALTA ARGENT MINE. SHOWING POSITION OF OPERATOR IN CHARGE OF HOIST.

shaft was 835 ft. deep, which depth is to be ultimately increased to from 1,200 to 1,500 ft. The condensed figures showing the operation of this hoist during the test are as follows:

Hoisting:	
Weight of bailer, 1,950 lbs.; water, 6,930 lbs.; total	8,880 lbs.
Counter-weight	5,125 lbs.
(The ropes balance, considering the entire trip.)	
Net weight raised	3,755 lbs.
Depth of shaft	835 ft.
Work, 3,755 × 835	3,135,425 ft. lbs.
Time hoisting	2.25 min.
Foot-pounds per minute	1,393,521 ft. lbs.
Mechanical HP., 1,393,521 ÷ 33,000 =	42.2 HP.
Lowering:	
Counter-weight	5,125 lbs.
Weight of bailer empty	1,950 lbs.
(The ropes balance, considering the entire trip.)	
Net weight raised	3,175 lbs.
Depth of shaft	835 ft.
Work, 3,175 × 835	2,651,125 ft. lbs.
Time of lowering	2.25 min.
Foot-pounds per minute	1,178,277 ft. lbs.
Mechanical HP., 1,178,277 ÷ 33,000 =	35.7 HP.

At the Alta Argent mine, also at Aspen, is another hoist This is placed at the head of the incline. The current is taken from the power plant of the Roaring Fork Electric Light & Power Co., 3½ miles distant, two miles being above the ground and 1½ miles through the Cowenhoven tunnel and mine workings. The hoist is also over-balanced and is equipped with a General Electric Company's multi polar slow-speed 500-volt motor, having a capacity of 20 HP.

The location of this hoist has been arranged especially for the convenience of handling the cars. The hoist is placed on a platform about 10 ft. above the level at the head of the incline, where the ore cars are stopped and run off after being hoisted. Here the hoist operator stands and handles his controlling levers and reversing switch. This arrangement gets the hoist out of the way, while it allows the operator to attend to the cars. In the case of other hoists at Aspen, the hoist is placed directly at the head of the incline. This relegates the operator to the back of the hoist, where he can see both shaft and rope when hoisting and lowering. To attend to the cars he would be compelled to pass around the hoist, and as this entails loss of time, a second man to handle the cars is usually necessary. At the Alta Argent one man suffices to operate the hoist and handle the cars.

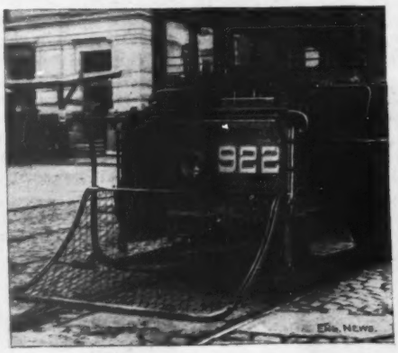
In the mines of the Pleasant Valley Coal Co., of Castle Gate, Utah, is another direct current mine hoist used for hauling the coal cars up the incline. This hoist is a Lidgerwood double-reduction single-drum machine, equipped with a standard L. W. P. 20 HP. railway motor and double 51 rheostat. It is designed to lift 4,000 lbs. 500 ft. per minute. The drum is 47 ins. in diameter and 36-in. face with two brake bands with V-shaped grooves on the drums. It is provided with both friction and positive clutches, and is operated by five levers—one for the rheostat, one for the friction clutches, one for the positive clutch and two for the brake. The dimensions of the base on which are mounted the drum, motor and controller, are only 78 ins. by 95 ins. Another hoist of similar pattern, but using a friction clutch only and a General Electric 2,000 motor with a double 83 rheostat has recently been added to the equipment of the Pleasant Valley Coal Co. The motor in this case is fully enclosed.

The three hoists just mentioned are in the West. In the mines of the Lehigh Valley Coal Company at Maltby, Pa., is a direct current electric hoist, very similar to that at the Castle Gate Colliery. The dimensions of the drum are the same, the General Electric motor is of similar capacity, but the controller is of the "N. R." type, with packed ribbon rheostats mounted separately from the base. It is designed to hoist 5,000 lbs. at a speed of 500 ft. per minute.

A NEW FENDER FOR STREET CARS.

A majority of the fenders now in use on street cars are attached simply to the car platform, and are open to the objection that they rise and fall with the vertical motion of the ends of the car (which is often very considerable, especially on four-wheel cars), so that they cannot be set very close to the pavement in any case, and when the car is pitching are at times a foot or more above it. In the Stanley fender, which we illustrate this week, there is at each end an iron extension built out from each truck frame, reaching to the front of the dashboard, where it is turned up vertically to form the attachment of the fender proper. These extensions are stiffened by cross bracing. The fender has a curved frame of steel, covered with rubber on the lower edge, and netting of any kind may be used to fill in the frame. It is attached and secured to the vertical posts by pins or by other means and held to the bottom of each post by a piston rod with a piston working in a cylinder containing a spring. These cylinders are hung on trunnions in jaws secured to the posts, so that they accommodate themselves to the position of the fender, being vertical when the fender is folded up. The effect of these attachments is that when the fender strikes any obstruction, its edge will be forced down close to the rail, no upward movement being possible.

This fender is placed at each end of the car, and it can be adjusted at any desired point above the



A New Street Car Fender.
Ira M. Stanley, Inventor.

rails, or folded up to a vertical position close against the dashboard.

One of these fenders has been applied to a car of the Brooklyn City R. R., Brooklyn, N. Y. It is the invention of Mr. Ira N. Stanley, of 310 Washington Ave., Brooklyn, to whom we are indebted for photographs of the device.

PAINTING FREIGHT CARS BY COMPRESSED AIR.

At the February meeting of the New England Railroad Club, the subject for discussion was "Is it Economy to Use Compressed Air in Painting Railway Equipment?" Letters were read from car painters in various parts of the country, all approving of this method and pointing out its economy and its efficiency as compared with hand painting. The saving in time is very great, and generally there is some slight saving in the amount of material used, while there is less waste than in the ordinary hurried painting of freight cars by hand, the saving in brushes is considerable, and the paint is quickly and properly applied to places that are not easily accessible by brushes. To get good results the nozzle must be handled skillfully, so as to apply the proper amount of paint, and yet not hold the nozzle so long in one place that the paint will run, in which case it will have to be touched up with a brush. In regard to the painting of grab irons and other ironwork a different color, the only way is to spray the car all over first, and then give the iron work the required color by hand, but the discussion showed a tendency towards approving one single color for the whole car, sprayed on over car body and trucks and given no further attention.

Mr. C. E. Copp, General Foreman Painter of the Boston & Maine R. R., said that he had little doubt as to the economy of this method of painting freight cars, when thoroughly perfected and well operated. One man painted equivalent to 29 standard 34-ft. coal cars in about five hours, which is an average of one every ten minutes, and the air pressure was poor. Various speeds of from five to ten minutes per car were realized at this work. This was for the car body and attachments only. Thus a great saving of labor was effected by this method, with fair results if not equally as good as those obtained by the brush, and the saving in brushes must be a large item. As to material, no more is wasted than by the brush generally, in fact, by a test made at the Pittsburg & Lake Erie R. R. shops, less was used by the spray method. But when computing the expense of painting by compressed air, the cost of the air should be reckoned in, as compression costs something.

If the yard is piped for air the work can be done in the open air in fine weather, but in cold weather the moisture is likely to freeze in the pipes unless the air is heated. The spray method requires care in handling, to get an even coat and prevent running. If a heavy paint was well worked into the wood by a hand brush it would no doubt be more durable than the sprayed paint, but on freight cars painted by hand the work is usually done hastily and with little care.

Mr. W. O. Quest, Foreman of Painting, of the Pittsburg & Lake Erie R. R., said that a heavier bodied coat of paint cannot be applied with the brush than can be applied with the spraying machine. In fact, the syphon sprayer can be made powerful enough to lift and perfectly atomize either a lead or metallic mixed paint weighing 16 lbs. per gallon, without detracting from the appearance or drying qualities of the work, and will look better than hurried painting done with a brush, where using a similar heavy-bodied paint, which, under such circumstances is rarely, if ever, brushed out. The comparative cost is shown in the accompanying table, which includes cost of knotting, ordinary cleaning, tack pulling, etc.:

	Piece Work. Hours.	Cost, cts.	With Spray. Hours.	Cost, cts.	Saving. Hours.	Cost, cts.	Per ct.
Box	3½	60	¾	15	2¾	45	75
Coal	1½	30	¼	10	1¼	20	66⅔
Coke	3	50	⅛	12	2⅞	38	76
Flat	½	10	1-6	05	⅓	05	50
Trucks—all cars		30	..	12	...	18	60
Roof only—box		10	..	04	...	06	60

The essential qualities of a good mixed spraying paint was found to be: 1, its fluidity, regardless of weight; 2, its oxidizing properties must be uniform, drying from the bottom out, and not from the surface in, thereby avoiding the flattening, shrinkage and other bad features, which invariably follow in the wake of all skin drying paints. The adopted spraying paint successfully made by the company weighed 10 lbs. per gallon; formulated by using 7 lbs. of a specially combined oil to 3 lbs. of the finest ground semi-paste metallic freight paint.

Mr. Kahler, of the Erie R. R., at Meadville, Pa., submitted a communication, of which the following is an abstract:

There is a little mist in the air when working in the shop, and the best results are obtained out of doors, when the atmosphere is quiet. For protection, the operator can wear goggles and sponge, but my men seldom do this, and in working out in the yard when the wind is stirring the operator favors himself by working from the right quarter. From this mist in the air while in operation, one forms the opinion that there is a great waste in the method, but if we take into consideration the fact that a spoonful of oil can be made to produce a great quantity of mist or spray, this idea is reduced to a minimum, and cuts no figure in comparison to the saving in time and brushes.

Our usual custom is to hold four men one hour after quitting time to paint eight box cars (or twelve gondolas, as the case may be), with two machines in operation. One man follows the operator to supply paint and look after the hose. The men come out again one hour earlier than the rest the next morning and apply the second coat. Here the man looking after the care of hose also lays on the second coat of paint, with a wide, long-handle brush, by one downward stroke, and the car looks as well as if painted by hand. These same cars are stencilled and completed by night. We use no scaffolding while applying the paint to the body of the cars, and in doing the roofs, the men step from one to the other along the line. The speed attainable in painting with air pressure is better understood when comparisons are made to hand painting on surfaces of many angles, small openings and inner places not reached by hand, and which ruin brushes to get at, and into them. For example, we will take one of our modern box cars, the end of which has a ladder, brake-staff and foot-board, with brackets underneath, automatic coupler and lift rigging, together with buffer castings, bumper blocks, etc., all of which make up a large surface to be done by hand. With the paint machine this is all painted thoroughly and completely, with no spot untouched, in three minutes. Can a man do this by hand in so short a time and do it well? The cost of maintenance is so slight that it cuts no figure. I have had two machines and 200 ft. of ½-in. rubber hose in constant use nearly two years. Where matched wooden roofing is used on cars, we paint the tongue and groove before laying, and do it very quickly and perfectly. To do this by hand requires much time, and in the end is not done as well as it can be done with the machine.

The air pressure is usually about 80 lbs. per sq. in., and in regard to the mist or spray produced it has been pointed out that this might be troublesome or even dangerous in a small shop with low ceilings and poor ventilation. The following statement of cost was submitted by Mr. H. G. MacMasters, Master Car Painter of the Illinois Central R. R.

Priming New 35-ft. Box Car by Hand.

Labor, 2 hours, at 20 cts.	$0.40
Material, 14 lbs. paint, at 5 cts.	.70
Total	$1.10

Priming New 35 ft. Box Car with Spraying Machine.

Labor, 35 min., at 20 cts. per hour	$0.12
Material, 12 lbs., at 5 cts.	.60
Total	.72
Total saving (34.57%)	.38

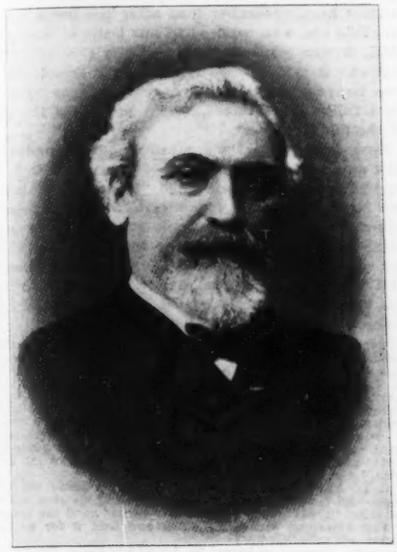
The saving of labor is 28 cts., or 70.83%. The saving of material is 10 cts., or 14.29%. Roof and trucks are not included. These figures include placing staging around the car, making all air connections, filling and cleaning the machine, replacing hose, etc., or the actual cost of priming one car. The cost of second and third coating varies slightly, but is materially the same as above.

Tests made on the Atchison, Topeka & Santa Fe Ry. showed that in painting 20 freight car roofs, half by hand and half by machine, and painting six 28-ft. box cars (not including roof) the comparative results were as follows:

	Labor.	Material.
Car roofs, by hand	160 mins.	11⅛ gallons
" " by machine	40 "	11¼ "
Car bodies, by hand	13 hours	9 "
" " by machine	1½ "	11¾ "

ALBERT FINK.

Mr. Albert Fink, Past President of the American Society of Civil Engineers, and the originator and first director of the trunk line pooling system,



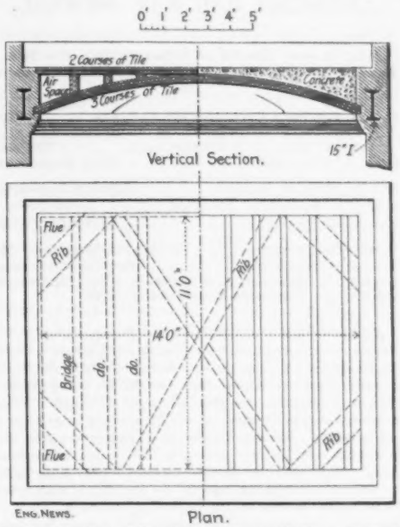
ALBERT FINK.

died of pneumonia at a sanitarium in Sing Sing, N. Y., on April 3. Mr. Fink was born in Lauterbach, Germany, Oct. 27, 1827, and was educated as an engineer in his native country. About 1850 he came to the United States and entered the service of the Baltimore & Ohio R. R. Co. He was first an assistant engineer engaged in bridge and station construction west of Cumberland; was then resident engineer at Parkersburg, and in 1857 he was also made consulting engineer to the Norfolk and Petersburg R. R. Co. Later, Mr. Fink went to Louisville as Chief Engineer and Superintendent of the Louisville & Nashville R. R.; from 1865 to 1870 he was General Superintendent of this line, and in July, 1870, he was made Vice-President, and was virtually President during the service in the U. S. Senate of James Guthrie, the President of the company. Early in his career upon the Baltimore & Ohio R. R., under Chief Engineer B. H. Latrobe, he invented the Fink bridge truss, extensively used some years ago; and from his patents on this he is said to have derived a large revenue. Mr. Fink designed and built the Louisville bridge across the Ohio River, the Nashville bridge over the Cumberland, the Decatur bridge over the Tennessee River, on the Memphis & Charleston Railway, the Fairmount bridge over the Monongahela River, built in 1851-52, and the Green River bridge on the Louisville & Nashville R. R., besides many others of less importance. It was while acting as Vice-President of the Louisville & Nashville R. R. Co., that Mr. Fink first began a minute investigation into the cost of railway transportation, and he embodied the results of his studies in a report to the Directors of that company. He soon after formulated a system for the pooling of railway earnings, which was adopted by the Southern Railway & Steamship Association in 1875. The system developed so successfully that the Trunk Line managers, in 1877, offered to Mr. Fink the joint commissionership of the New York Central, the Pennsylvania, the Erie and the Baltimore & Ohio railway companies. Mr. Fink accepted the trust and the trunk-line pool was organized by him in June, 1877, including the four companies named. The system proved so generally profitable, as compared with the old rate-cutting methods, that in six years thereafter forty of the largest railway companies in the United States had entered into it, and Mr. Fink found work for a staff of several hundred clerks. For nearly twelve years he kept the great pool intact and maintained uniform rates with but a few serious breaks in the harmony of the pooling companies, but in 1889 Mr. Fink resigned his onerous position as Pool Commissioner, with its salary of $25,000 per annum. Mr. Fink was accused of having been brusque and autocratic in his dealings with railway magnates, and they did not always take his advice. He estimated that the bitter rate war, waged against his advice for eight months in 1881, cost the companies engaged in it over $30,000,000. Albert Fink became a member of the American Society of Civil Engineers on July 20, 1870, and was elected President of that Society on Nov. 5, 1879. One married daughter survives him.

TEST OF THE GUASTAVINO FIREPROOF FLOOR.

A test was made on April 2, by the Building Department of New York city, at the testing grounds, 68th St. and Avenue A, of the system of fireproof floor construction of Mr. R. Guastavino, 11 East 59th St. The test was made in the same manner as the other tests which have been described in our columns during the past six months. The floor was built so as to form the roof of a brick building, 11×14 ft., inside dimensions, and about 12 ft. high. An illustrated description of this system of flooring as used in the Boston Public Library building, and in the Arion Club building in New York city, was given in our issue of Nov. 9, 1889. The construction used in the test is shown in the accompanying cut. The principal feature of the construction is an arch formed of three layers of a hard, well burned clay tile, about 1 in. thick, 6 ins. wide, and 12 ins. long. The lower layer is laid with a quick-setting mortar, composed chiefly of plaster of paris; the other layers are set in a mortar of Portland cement. The thrust of the arch is taken by I-beams, built in the walls, and four shorter I-beams placed diagonally across the four corners. The rise of the arch is 1.1 ft., or 1-10th of the span. The flat floor above the arch was built in two forms, as shown in the cut, one on each side of the center line. On one side it was made of two layers of tile, set in cement, with supporting ribs, enclosing air spaces, and on the other the whole space up to the floor level was filled in with concrete.

Previous to the test the floor was loaded with pig iron to 150 lbs. per sq. ft. With this load the floor showed no deflection. During the test a fire of cordwood was maintained for five hours on the wrought-iron grate near the ground floor of the building, and a second grate, 1 ft. below the first, caught the hot embers by which the air admitted to the fire was heated. The temperature of the rom below the arch was measured by a Uehling & Steinbart pyrometer. At the end of the first hour after starting the fire the temperature had reached 1975° F., and thereafter, until the end of the test, it ranged from 2,000° to 2,500°. The fire on the average was hotter than any of the previous tests by the Department, which was probably due to the warm, dry weather which prevailed, and the dry condition of the firewood. During the fire, instead of any deflection being shown, the floor rose ¾-in., by measurement at the center, the rise being caused no doubt by the expansion of the materials of the arch. At the end of five hours the fire was quenched by a powerful stream of water from a fire engine, 60 lbs. gage pressure being maintained at the engine. The stream was directed against the under side of the arch. The force of the stream and the sudden cooling detached some of the tiles of the lower layer, but the remainder of the arch was uninjured, and sustained the load. The deflection, measured after the cooling by water, was 0.22 in., but when the load was removed the arch rose 0.05 in., so that the final deflection was 0.17 in. The next day the arch was loaded again with a burden of 600 lbs. per sq. ft. (over 50 tons in all), the loading taking about six hours. During the loading the floor gradually deflected to a total of 0.37 in., at which it remained. The ceiling where the tiles were detached is to be repaired, and another fire and water test is to be made of the same arch in about ten days.



Plan and Section of Guastavino Fireproof Floor, Subjected to Fire Test by the New York Building Department, April 2, 1897.

IN THE CASE OF THE BOWER'S HYDRAULIC Dredge patents, U. S. District Judge Hanford, sitting at Tacoma, lately rendered injunctions against the San Francisco Bridge Co. and the New York Dredging Co. Judge Hanford held that the dredges operated by these two companies at San Francisco, Boston, Washington, Florida and Texas, commonly known as the "Atlas" type, were infringements of the Bowers patents. In this case the defendants presented new evidence, not used in the von Schmidt case, and contended that the effect of this evidence was to modify the scope of the Bowers claims, but the judge held that this evidence was not sufficient to justify him in withholding the injunctions, which he then granted.

THE NEW U. S. MINT, AT PHILADELPHIA, is to be commenced shortly, says the "Times" of that city. The new building will cover the block bounded by 16th and 17th streets and Spring Garden and Buttonwood streets, and the estimated cost is $1,652,000. It will be in the form of a hollow square, with a frontage of 316 ft. The work of excavating the foundation is already in progress, under Allen B. Rorke, the contractor.

A LARGE FLOW OF NATURAL GAS was obtained by drillers at Rome, N. Y., on April 3. The well was drilled to about 1,000 ft. in depth, when the flow suddenly began with a roar that was heard several blocks distant.

A BLOCK OF SLATE WEIGHING OVER 1,000 TONS was dislodged and moved 6 ins. from its natural bed by a blast of only 40 lbs. of powder at the quarries of the Chapman Slate Co., near Bethlehem, Pa., on March 30. The block measured 67 ft. long, 14 ft. deep and 13½ ft. wide.

THE SPONSEL RAPID-FIRE GUN PATENT has been purchased outright by the U. S. Navy Department for $15,000, on the recommendation of Capt. W. T. Sampson, Chief of Bureau of Ordnance. This action is said to have been taken to protect the government from any attempt to raise the contract price of rapid-fire guns made by the American Ordnance Company, controlling the Driggs-Schroeder, Dashiell, Hotchkiss and some other rapid-fire gun patents. The gun invented by Mr. Charles W. Sponsel, of Hartford, Conn., was tested by the Navy Department, two years ago, in competition with the Driggs-Schroeder and Hotchkiss guns, and Capt. Sampson believed it possessed sufficient merit to warrant the purchase of the patent.

ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

Published every Thursday at Tribune Building, New York. Entered at the Post Office, New York, as Second Class Matter.

D. McN. STAUFFER, CHARLES WHITING BAKER.....EDITORS.
WM. KENT, E. E. R. TRATMAN, M. N. BAKER, } ASSOCIATE
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ALFRED E. KORNFELD, New York..... } ADVERTISING
F. A. PECKHAM, Chicago..... } REPRESENTATIVES.

PUBLICATION OFFICE.....Tribune Building, New York.
CHICAGO OFFICE.....1636 The Monadnock.
LONDON AGENCY: { SAMPSON, LOW, MARSTON & Co. (Limited), St. Dunstan's House, Fetter Lane.

SUBSCRIPTION RATES: United States, Canada and Mexico, One Year, $5.00; 6 months, $2.50; 2 months, $1.00; Single copies, 15 cents. To all other countries in the Postal Union: Regular Edition, One Year, $7.60, (31 shillings); Thin Paper Edition. One Year, $6.31 (26 shillings). Mailing addresses may be changed at will by sending both old and new address. We shall be obliged if subscribers who fail to receive their papers promptly will notify us without delay. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 326 means that subscription is paid to the 32d week (that is the issue of Aug 6) of the year 1896; the change of these figures is the only receipt sent, unless by special request.

ADVERTISING RATES: 20 cents per line agate measure. Want notices, special rates, see page 22. Rates for standing advertisements sent on request. Changes to standing advertisements must be in hand on Monday afternoon; new advertisements, Tuesday afternoon; transient advertisements by Wednesday noon.

In the course of the public discussion over the proposition to run through cars over the Brooklyn Bridge, various distinguished persons, including some prominent in the administration of the bridge affairs, have expressed the idea that an "all railroad bridge" parallel and close to the present structure ought to be built across the East River. During the past week the newspapers have given especial prominence to this idea. There is probably not the remotest likelihood that anything will come of the talk; but it seems worth while to point out the foolishness of such a scheme. It appears to be forgotten that a bridge is now actually under construction by the two cities at a point a couple of miles or so above the present structure. When through elevated and electric surface cars are running across both this structure and the present Brooklyn Bridge, it will in all probability be found that the traffic facilities will be ample to meet all demands. Of course, steady and rapid growth in the volume of traffic is certain to continue; but the sensible plan will be to provide for it by building bridges or tunnels at various points along the course of the river instead of concentrating it near the lower end of Manhattan Island. As a matter of fact, the present bridge is substantially an "all railroad bridge." The traffic of foot passengers and vehicles across it is so trifling that the structure would be a financial absurdity if that traffic alone was accommodated by it. The only sensible course to pursue is to utilize the capacity of the present bridge to the fullest extent for railway traffic, and as the travel grows up to this capacity, provide additional facilities for crossing the river at other points.

Since our "Chapter of Curiosities" in our last week's issue was completed, our crank drawer has been enriched by several specimens so choice that it seems best to share them with our readers at once instead of waiting until the date of another issue falls on All Fools' day.

The most precious of this latest consignment is a "geodetic survey which is now being conducted on the coast of Florida for the purpose of showing that the surface of the earth is concave, instead of convex, as men have long perversely believed. Our information is gleaned from the Fort Myers, Fla., "Press," which describes with considerable detail and profundity this remarkable enterprise. We regret that our space permits only the following brief extract:

> The scientific work of the Geodetic staff of the Koreshan Unity, operating at Naples, Florida, has been in progress for a number of weeks.
>
> Prof. Morrow now reports that a number of observations and experiments have already been conducted, all of which he claims to be favorable to the Koreshan theory of the Earth's concavity.
>
> A remarkable fact which is reported to us is that of a steamer in the southern horizon, only the smoke was visible to the naked eye, the body of the steamer being entirely out of sight. Through the staff's large mounted telescope, the whole of the body of the steamer was brought into view, even down to the water upon which it sailed. The staff is making many special observations of various phenomena upon the Gulf shore, and will no doubt collect a number of facts before the expedition returns to Chicago.
>
> The new geodetic apparatus, invented by Prof. Morrow, is one which is attracting the attention of scientific men. It is the only apparatus of the kind in the world, and with it Prof. Morrow and his staff expect to show whether the earth's surface is convex or concave. The method of use of this apparatus, called the rectilineator (an instrument to run a straight line) is that of leveling the first section or double-T straight edge, at right angles to the perpendicular at starting point of survey. From this leveling section a straight line is mechanically forced by applying the principle of right angles—that of adjusting the second section to the first, the third to the second, etc., and so on throughout the line of survey.
>
> This line of geodetic survey will certainly be watched by our people with interest, as it is the first mechanical test of the contour of the earth that has ever been made.
>
> On March 15 the work of survey of the line began, which is to determine for the world the true contour of the earth. The work is tedious and requires much time, but at the time of this report (March 25) one-eighth of a mile has been accurately surveyed. A system of tide measurements has been introduced, and upon record stakes set at every eighth of a mile, a line indicating 10 ft. above the water, so that it is easy to determine as the work progresses, whether the line is running favorable to the convex or the concave theory. If the earth should be rotund or convex, the air line surveyed by the apparatus should run above the measurements; if concave, below. At the end of the first eighth of a mile it was found that the air line was about one-eighth of an inch below the line of measurement upon the record stakes. At this point, also, levels were applied which showed that the line is deviating slightly from the level, which is decidedly in favor of the claims for the concave theory.

We have no doubt at all that the line which "Prof." Morrow's "rectilineator" will produce will gradually approach the earth's surface, exactly in accordance with the "Koreshan" theory, and thereby prove that the earth is concave instead of convex. The people who are convinced by this "proof" will doubtless be at the same time relieved of the secret fears of falling off the earth, which they have entertained in the past.

If our memory rightly serves us, however, this concave earth idea was agitated some years ago, and at that time it was proposed to make a "rectilineator" survey along the shore of Lake Erie. Judging by the appreciative newspaper article from which we have quoted, the Koreshans were wise in transferring their surveys to Florida. We respectfully commend to Prof. Morrow the treatise by John Phoenix. His work is a standard authority upon geodetic surveys of the Koreshan class.

The next specimen on our list is a new power generating machine for which one Chas. E. Tripler, 40 West 77th St., is responsible. From an account in the New York "Press," of March 31, and April 1, it appears that the source of Mr. Tripler's power is liquefied air. Given a certain amount of liquefied air to start with, and his machine not only develops power in great quantity but liquefies more air to keep up its own supply—according to the inventor's story. He strenuously denies, however, that he is creating power, and declares that he "gets power by utilizing the energy of the sun's rays." The liquid air in his process "is just what the ashes are to coal in the production of power by burning coal," etc., etc.

It appears that Mr. Tripler stimulates his liquefied air by mixing a little alcohol with it. He was exhibiting something or other in connection with his apparatus to a group of prospective investors at the Hotel Endicott, on March 27, when some inquisitive person touched a match to the compound. An explosion followed, and several of the investors were picked up considerably the worse for wear From which it appears that credulity is sometimes dangerous to the person as well as the pocket.

We paid our respects to the "Holman Locomotive Speeding Truck Co., capital stock $10,000,000," in our issue of Feb. 25, at the time the company inserted huge advertisements of its stock in the Philadelphia daily papers. The New York "Herald," of April 4, contains another quarter page advertisement, from which it appears that the subscription books, which were to open on Feb. 25 last "and close without notice" are to open again on April 22, and again "close without notice." From the advertisement it appears that the company has offices in New York, Philadelphia, Minneapolis and Sioux City, which indicates apparently that it is more interested in selling stock than in selling locomotives. Probably it is easier to sell stock. The contract to equip two locomotives for the South Jersey R. R., is thus far the only tangible evidence which the company offers as a reason for its enormous capitalization. It is interesting to note in this connection that the South Jersey R. R. is 66 miles long, owns 2 locomotives, and is in the hands of a receiver. What justification can there be for a court which permits the frittering away of money that belongs to the creditors of a corporation on such devices as the Holman speeding truck? Or for that matter what justification is there for a newspaper which permits the use of its advertising columns by the promoters of such a scheme?

We close our list of curiosities with a brief mention of a concern with which our readers are already familiar—none other than the old "Indestructible Pile Co., Geo. W. Dunn, Esq., President and General Manager," under a new name. Our readers may remember that after the Indestructible Pile Co. was exposed in our issue of May 16, 1895, it was rejuvenated under the title of "The Railway & Dock Construction Co." A fraud order was issued against this concern last year by the Post Office Department, which prevented its use of the mails.

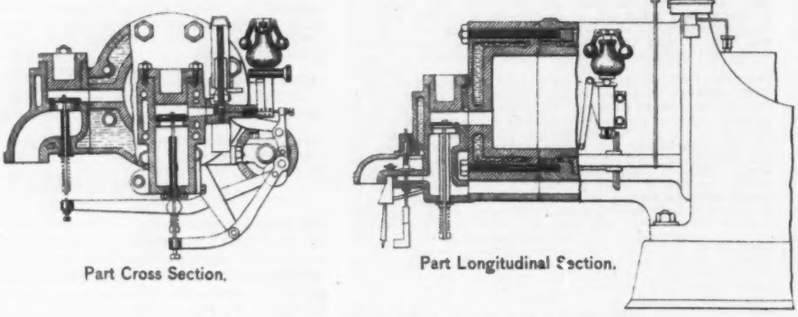
Now, however, the old scheme bobs up under a new name. A recent number of "The Wall St. Reporter" has an article headed "Information about the New Bonanza," which is a thinly disguised advertisement for the same old scheme, which now poses as the "American Stone Pile Co." There is the same old list of names of "eminent financiers," and in many parts the article is identical with the circulars formerly issued by the enterprising Dunn. We insert a few choice extracts:

> There are many rumors whispered about in financial circles that the company has already closed the contract with Holland and also the one for building the jetties at St. Louis (jetties at St. Louis is excellent.—Ed.) and for the foundations for the turret forts and for stone piers for several cities, and for trestlework on a number of railroads. The officials, however, politely decline to confirm or deny the rumors, but, after a number of diplomatic questions the significant fact was reluctantly admitted that "the company had no stock for sale now at any price."
>
> H. L. Bowdoin, 2 Wall St., New York (same old address.—Ed.) makes a specialty of dealing in this stock. He says: "I advise my personal friends to send me orders to buy American Stone Pile stock and hold it for an immense advance."
>
> Anyone inclined to invest in American Stone Pile stock should call on or address Mr. Bowdoin. "A word to the wise is sufficient." The secret of making money lies in the old Greek proverb, "Kairon Gnothi"—Know your opportunity.

Hardly a day passes that the police courts of this city are not called upon to sentence some poor wretch for petty thieving committed to satisfy the pangs of hunger; but those whose sworn duty it is to execute and enforce the laws appear to be entirely oblivious to the acts of those criminals whose trade is the defrauding of the ignorant and the credulous, under the cover of legitimate business; and they carry on their work year after year absolutely unmolested.

It begins to look as if the compressed air nozzle was to become the most used tool in the painter's trade. We publish on another page of this issue a summary of some recent expressions on the subject of painting freight cars by compressed air, which are practically unanimous in favor of that method. The painter's trade is an exceedingly conservative one, and it is safe to say that if the new method had not shown a very material saving in the total cost over the old system of application of paint by hand brushes, it would never have been adopted so extensively in this field in such a short time. As most of our readers will recall, the practical use of compressed air for painting began with the buildings of the Columbian Exposition of 1893. These enormous structures were painted, or rather sprayed, with kalsomine by compressed air machines. In fact it would have been a practical impossibility to have covered them by hand brushing within the limits of reasonable expense.

In this first work it was estimated that the



Part Cross Section.

Part Longitudinal Section.

FIG. 24. ANDREW-OTTO ENGINE OF MODERATE POWER.

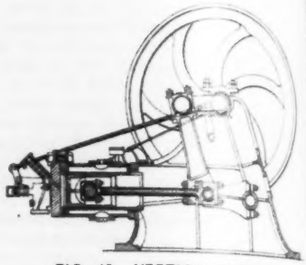


FIG. 48. VERTICAL SECTION OF ATKINSON'S CYCLE GAS ENGINE.

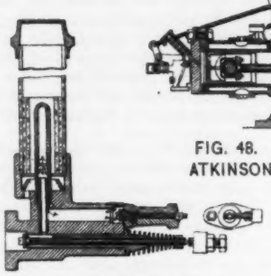
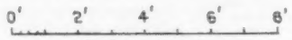
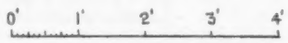


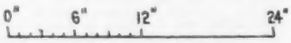
FIG. 25. SECTION OF ANDREW-OTTO COMBINED TIMING AND STARTING VALVE.



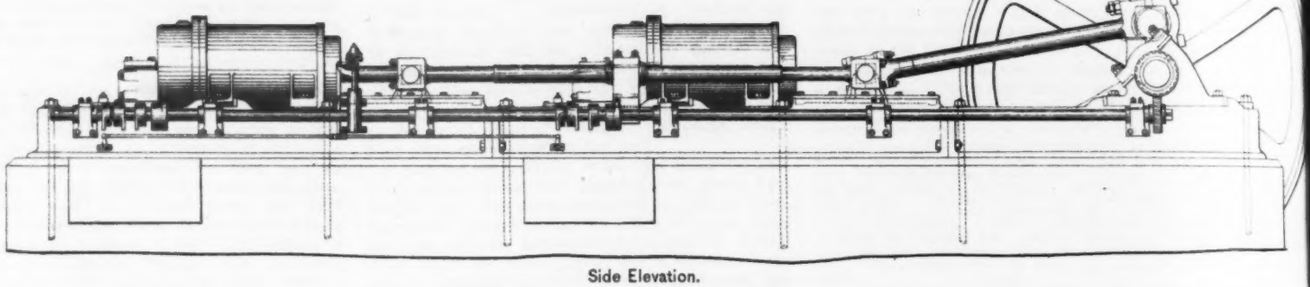
Scale for Fig. 23.



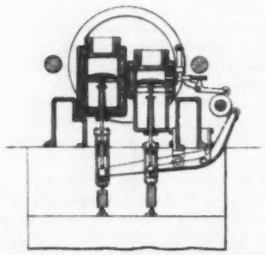
Scale for Figs. 35, 36, 44, 46 and 48.



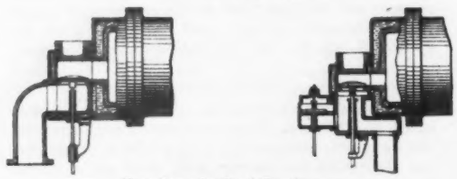
Scale for Figs. 24, 25, 38 and 39.



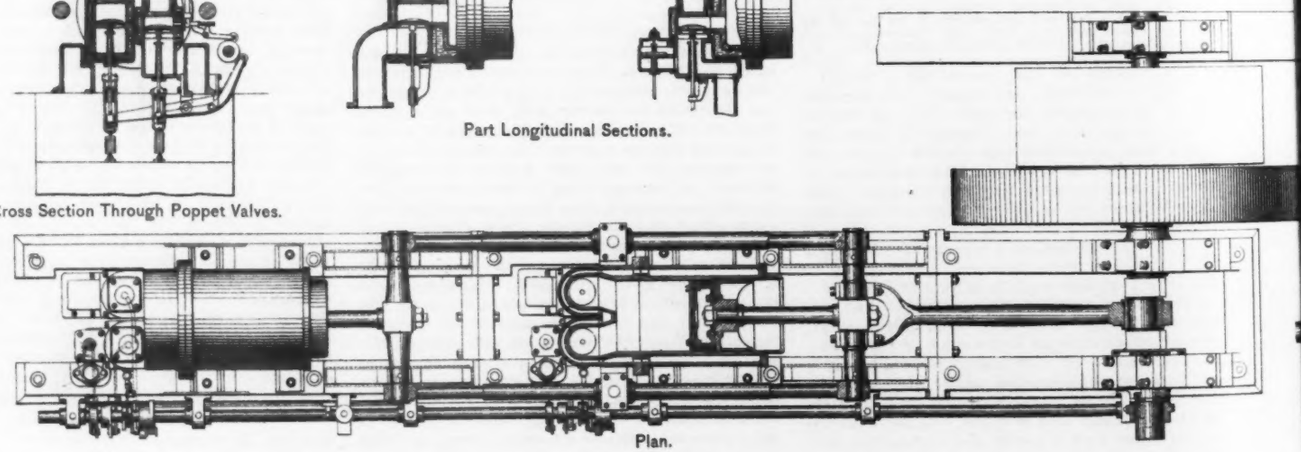
Side Elevation.



Cross Section Through Poppet Valves.



Part Longitudinal Sections.



Plan.

FIG. 23. PLAN, ELEVATION AND SECTIONS OF ANDREW-OTTO ENGINE OF 400 H.P.

RECENT ENGL

(From a Paper by Dugald Clerk, Assoc. M. Inst. C.

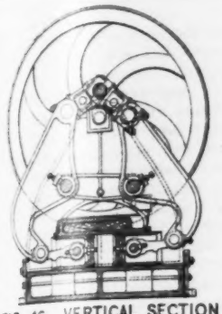


FIG. 46. VERTICAL SECTION OF SON'S DIFFERENTIAL GAS ENGINE, 1885.

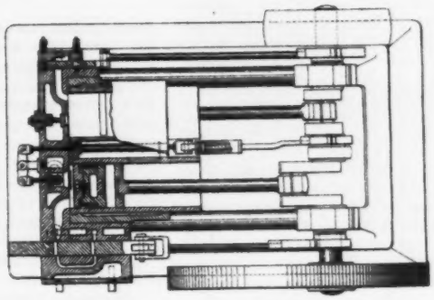
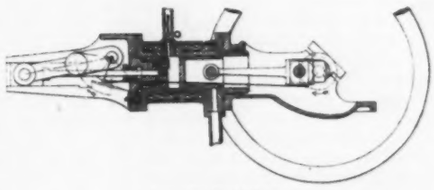
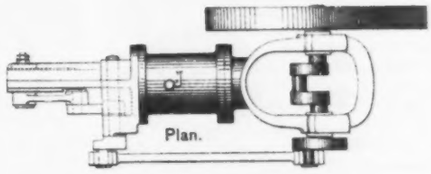


FIG. 35. CLERK GAS ENGINE OF 1878.

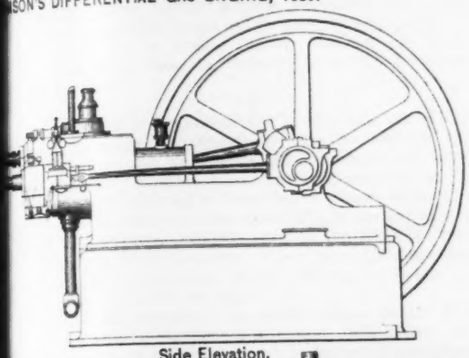


Longitudinal Section.

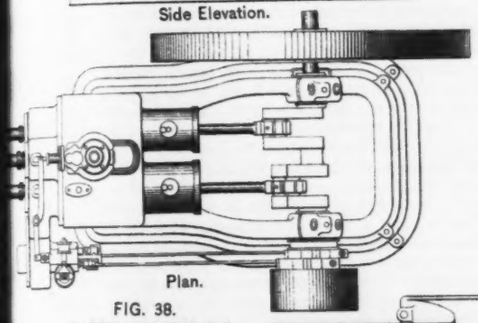


Plan.

FIG. 44. CLERK GAS ENGINE OF 1889.

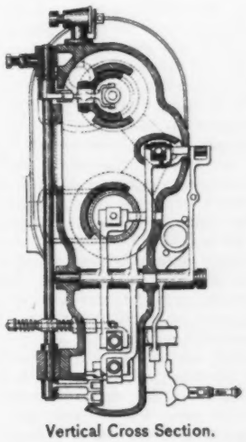


Side Elevation.

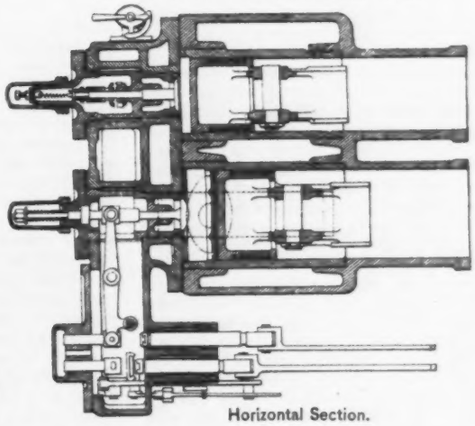


Plan.

FIG. 38.
CLERK GAS ENGINE
OF 1886.

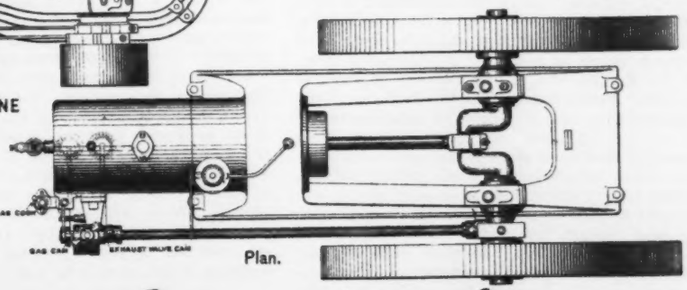


Vertical Cross Section.

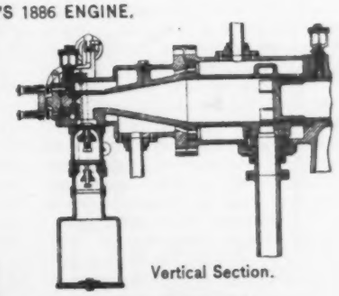


Horizontal Section.

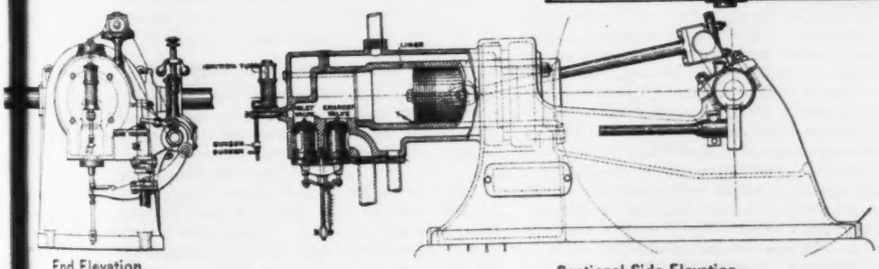
FIG. 39. CLERK'S 1886 ENGINE.



Plan.

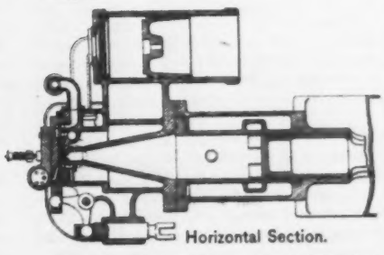


Vertical Section.



End Elevation.

Sectional Side Elevation.



Horizontal Section.

FIG. 36. CLERK GAS ENGINE OF 1881.

FIG. 26. BARKER-OTTO ENGINE OF 12 H.P.

ENGL GAS ENGINES.

M. Inst. C. Read before the Institution of Civil Engineers.)

CHAS. HART & SONS, LITH., 99 VESEY ST., N. Y.

amount of color used was 50% or more in excess of what would have been used with hand brushing. Since that time, however, the process has been so improved and perfected that it is possible now to apply paint as well as kalsomine, and a skilful workman will use no more material to cover a given surface than is needed to do good work with a brush.

But while this new invention is making rapid progress, it is also true, doubtless, that many are in ignorance of it, or are delaying its adoption who could save large sums by its use. There are hundreds of dark and dismal shops covered with heavy wooden roof trusses, black with accumulations of smoke and dust, where a few dollars worth of kalsomine would work wonders in lighting up the interior, thus saving in artificial light and facilitating work the year round. By using some fire-retarding chemicals in the kalsomine, the risk which at present exists of a fire gaining lodgment in these old timbers, dry as tinder, and sweeping through the whole shop before it could be checked would be greatly lessened.

Again for painting large surfaces such as roofs, trainsheds, freight houses, piersheds, etc., the compressed air plant can be used with economy in hundreds of places where brushes are still claimed by those in authority to be "good enough for them."

But there is another and totally new use of the compressed air nozzle of special interest to painters and that is its use in connection with sand for cleaning metal surfaces preparatory to painting. We have described in recent issues the tests which have been made of this system on the U. S. Cruiser "Atlanta," and on the 155th St. viaduct in New York city. These tests have aroused great interest in the process among the engineers who witnessed the work.

In the extended discussion upon paints and painting of structural iron and steel which has been carried on in current engineering literature for some years, all authorities, whatever their differences on other points, have agreed that no paint can be an effective and durable preservative of the metal on which it is placed if it is not laid on a clean surface. Mill scale, rust, grease, oxide, old and scaling paint, are all poor foundations on which to build an effective protection. Proper cleaning of the surface of the metal is everywhere insisted upon; but the question that no one has yet solved is how to effect such cleaning. To thoroughly and actually clean off a coat of old paint from a bridge or roof truss, using ordinary scrapers and hand tools, would be so expensive a task that no one has ever undertaken it. The sand blast process is the first means ever made practically available for doing this; and its measure of success in general use will be looked for with much interest. There seems no reason at all to doubt that where a large plane surface is to be cleaned, such as the hull of a vessel, for example, the process can be applied to great advantage in practice. Whether it can also be successfully applied to cleaning surfaces so difficult to get at as the interior of latticed struts, or the members around the panel point of a truss, is a question which experience alone can determine.

THE STORY OF A GREAT INVENTION.

Elsewhere in this issue we present a description of the system of converting heat into power, which was invented by the late A. M. Wellington, and to the development of which the last years of his life were devoted.

Many of our readers may recall an editorial in our issue of Sept. 15, 1892, with the title "Future Dynamic Possibilities." Any one familiar with Mr. Wellington's peculiar and vigorous style could not fail to recognize it as from his pen. He set forth in it the well-known wastefulness of the steam engine of to-day and showed that the man whose name is the most famous in connection with the development of the steam engine—James Watt—really owes his fame to the very simple discovery that it was more economical to condense steam in a separate vessel than it was to inject a jet of water into the cylinder itself. Since Watt's day, improvements upon the steam engine have been in matters of detail only, and we have at present arrived at a point so near the possible limit of economical working that future improvements in the steam engine in its present form must be of comparatively small effect.

The article then proceeded to discuss the possibilities that some man, "by thinking a thought perhaps as simple as Watt's," might open the door for a great revolution in our methods of generating power. Using Mr. Wellington's own words:

> We have every reason to believe that means which even we will recognize as simple when we can look back upon them may ere long carry us as far beyond the steam engine era as that is beyond the dark ages which preceded it.

At the time Mr. Wellington wrote these words he believed that he himself was on the eve of a great invention in the economical generation of power. Very soon after that he gave up practically all his energies to the development of this invention and labored with such zeal that his health gave way two years later.

His work on the invention was thus interrupted before an actual working engine had been built and tested, and from that point of view his work was incomplete; but the details of construction had been elaborated with remarkable fullness, and the thermo-dynamic theory of the invention had been so fully developed that its correctness and soundness can be positively affirmed. Elsewhere in this issue we have described in as simple a manner as possible Mr. Wellington's invention. We propose here to discuss some of the basic principles which underlie it, and which we believe to be not only entirely novel, but of great importance to the future development of the art of transforming heat into mechanical work.

The first of these principles we may define as the transfer of heat between two fluids at different temperatures, with far greater efficiency than is now possible. The only devices for this purpose which the mechanical engineer of to-day knows are the boiler and condenser. Each of these, but especially the former, requires a large space and weight for the transfer of a comparatively small amount of heat. But each of these, no matter what its form, is nothing but so many square feet of heating surface (or cooling surface). Suppose now it were possible to compress ten, twenty or fifty times as much heating surface in a given space, and make at the same time a proportionate reduction in the cost per square foot of heating surface. It will be readily seen that it would then be possible to effect heat transfers far more economically than now, and practical results of very great importance might follow.

For example, every student of thermodynamics is aware of the fact that in any place where two bodies exist at different temperatures, there is a potential source of power. A cold mountain brook flows into a warm river; the difference in temperature of the two streams is as real a source of possible power, as is the elevation down which one stream falls to reach the other. We can pass the water of the warm stream through the tubes of a boiler, and in that way impart heat to a volatile fluid contained in the boiler, such as ammonia, for instance, We can use the vapor to operate an engine and exhaust it to a condenser, which is cooled by the water of the cold brook. Even with our present commercial boilers and condensers, this would be possible; but of course the amount of power obtained would be trifling compared with its cost. With boilers of the vastly greater efficiency which we have suggested above, however, it might be a commercial success.

The above is, of course, only a single example. There are numberless places in nature where currents of air or water exist with differences of temperature from a few degrees to a hundred or more. It is quite possible that the engineer of the future will investigate the dynamic possibilities of all such places as the engineer of to-day investigates the available power of a waterfall.

But besides the natural sources of heat which such a boiler might enable us to utilize, it would also enable us to use to far greater advantage than at present the heat which we obtain by burning coal to develop power. The series engine invented by Mr. Wellington is an example of this. The reader who follows our description of this in another column can not fail to be impressed with the remarkable originality of this conception and its total departure from the beaten track of invention which it represents.

Mr. Wellington made this invention and then perceived that while theoretically sound, its practical success would depend on the invention of an entirely new form of heat transferring apparatus, and he turned all his energies to the accomplishment of that task. The results of his work we have briefly set forth in the article elsewhere. While he did not carry that work to a final success, his conception of a boiler consisting of thin parallel corrugated plates with the fluid to be vaporized and the fluid which is to impart heat to it flowing in alternate compartments, is one which may eventually become as important to mankind as the conception of the multitubular steam boiler.

But the series engine invented by Mr. Wellington which we have described elsewhere in this issue, is by no means the only important system of converting heat to power which would become practicable through such a heat transferring device as we have described. There are, in fact, several such systems, which were invented by Mr. Wellington, and will be found described in his patents. One which will readily occur to the reader is the utilization of the heat rejected in the exhaust steam of an ordinary steam engine. Suppose we were to pass such exhaust through the tubes of a boiler containing some volatile liquid such as ammonia. Evidently the ammonia vapor thus generated could be used to drive a second engine, and thus a large amount of power would be developed from heat which would otherwise have gone to waste.

The most promising of all these various inventions, however, and the one which appears likely to transform into power a larger percentage of the heat developed by combustion than any other system is the combination of a gas engine and a series engine. The best modern gas engines can furnish a horse-power hour with a fuel consumption of only about 1 lb. of coal, or they transform into mechanical work about 20% of the total heat generated by the combustible which they use. Of the remainder of this heat, from 65% to 75% is carried off by the cooling jacket water and by the exhaust. Now with a compact heat transferring device, it would be possible to use the heat which now goes to waste from the gas engine, to operate a Wellington series engine, which would convert into power perhaps 20% or more of this heat. As some gas engines have given records of thermodynamic efficiency as high as 27% it will be seen that it is quite within the possibilities that through some such combination we may yet be able to actually transform into power as much as 50% of the heat developed by the combustion of fuel. The vast economic revolution which such an invention would effect can hardly be underestimated. The ordinary steam engine of fair economy transforms into work only about 10% of the fuel it consumes; and the very highest records of the most economical pumping engines are below 20%.

The demand for cheaper power is an enormous one. The ordinary steam engine is approaching the limit of its possible economy. Higher steam pressures combined with superheating are at present the only directions in which any considerable improvement is possible. Dr. Thurston, in an able discussion of this subject at the last meeting of the American Society of Mechanical Engineers set 7 to 8 lbs. of steam per I. HP. per hour as a probable practical limit to gain in efficiency through these means.

The electrical engineers are looking for some method of consuming carbon in a battery, so as to transform its chemical energy into electrical current; but notwithstanding the sweeping claims of one or two inventors, nothing so far made public shows any prospect of success in this field.

We are within bounds, then, in saying that the Wellington engine, if it is made a practical success, promises the highest economy in the conversion of heat into power of any heat engine ever made. As such, it is certainly worth the careful study of engineers and scientists generally; and it is with that purpose that the articles in the present issue have been prepared.

We have called Mr. Wellington's invention great; but it may be objected that its greatness is yet to be proved by its actual construction and

operation. To the world at large the great inventions are those which yield the largest money returns; and it has often happened that these have come from the simplest and most trifling things. The man who hit first upon some fundamental detail like the sewing machine needle of Howe, or the rubber vulcanizing process of Goodyear, and was fortunate enough to secure broad patent protection upon it has frequently reaped enormous rewards.

But it seems to us that the educated engineer should give a broader answer to the question what constitutes a great invention. Not mere money return to the inventor is the real criterion of the great invention, but, How great a task did the inventor accomplish? What measure of originality over his fellows laboring in the same field did the invention display? and finally, What are the broad economic effects which have resulted from it upon the world's commerce and industry?

The future alone can answer the last of these questions; but as respects the first two we believe the invention of Mr. Wellington is entitled to rank among the greatest of original creations in the field of the transformation of heat to mechanical energy.

The ordinary course of engineering development is a step-by-step process. Each inventor improves only some small detail in the work of his predecessor. There are few cases where a man departs entirely from the beaten path and explores a wholly new field. When he does so he finds, in nine cases out of ten, that others are simultaneously pursuing the same idea, and it is a neck-and-neck race for the precedence.

But in this invention of Mr. Wellington's an absolutely novel process in thermodynamics was discovered. The patent office records showed that no prior inventor had patented even the most elementary conception of this system. Simple in its principles, it had yet remained an undiscovered country, of which not one of the hundreds of investigators in the field of thermodynamics, in all the nations of the world, either as student, professor, experimenter or inventor had ever dreamed.

What its future record will be in the field of practical application, time alone can determine. It is probable, however, that its development henceforth, like that of other great inventions, will be a step-by-step process. Its success will not be achieved at once. If, however, its theoretic possibilities are finally realized and it becomes possible through its agency to halve the cost of the world's supply of power from heat, its right to be considered a great invention and a perpetual monument to its originator will be questioned by none.

LETTERS TO THE EDITOR.

Elevation of Outer Rail—Correction.

Sir: Inasmuch as you have printed a portion of my article on "Elevation of Outer Rail" in your last issue, will you be good enough to note the following erratum: The second value for V, given on your page 182, and derived from equation 3, should be $V = 1.522 \sqrt{R}$.
or in general for any maximum cant c,

$$V = \sqrt[4]{\frac{223.64\, c^2 R^3}{G^2 - c^2}}$$

Very truly, Wm. G. Raymond.

Rensselaer Polytechnic Institute, Troy, N. Y., March 29, 1897.

(A correspondent also calls our attention to the fact that in our issue of Mar. 25, the track gage of 4 ft. 8½ in. was incorrectly expressed as equivalent to 4.9 ft. This should read 4.7 ft. in equations 2 and 3. The misprint was copied from the original article in the Troy "Polytechnic."—Ed.)

The Rondinella Tetrangle and Double Triangle.

Sir: In your issue of March 25 you print an article describing Prof. L. F. Rondinella's tetrangle and double triangle, and say at the bottom of the column, "Sold by Keuffel & Esser Co., N. Y." We do not know whether you have been authorized to do so by any one, or if a mistake is made, and would ask you to kindly inform us. This firm holds the only contracts from Mr. Rondinella for manufacturing both of these instruments.

Yours respectfully, The Lutz Co.

Guttenberg, N. J., April 1, 1897.

(Our foot note referred to the scale of Proportional Inches only; and it was made without the authority of Prof. Rondinella, but from what we interpreted as the stamp of the firm mentioned on a small cut of the scale, not reproduced by us. The foot note has no reference whatever to the tetrangle and double triangle, as our correspondent will see by more carefully reading the article. —Ed.)

Tests of a Cahall Boiler at the Armstrong Cork Works, Pittsburg, Pa.

Sir: I read with interest the editorial opinion expressed in your issue of March 18 regarding the alleged evaporation in the Cahall boiler as tested by Thos. Pray, Jr., also the reply in the issue of April 1, by the Cahall Sales Dept., together with your comments thereon. I admire both the reply and your comments, though for quite different reasons.

That any first-rate boiler company in America can be found in the year 1897 ready to risk its reputation for common sense, not to say honesty, on the data presented in the test referred to, is truly remarkable and affecting. But what of the nerve required in him who would proceed defiantly to defend the aforesaid data in the face not only of your editorial, but of common knowledge? One's head swims with the vernacular of our beloved country in attempting to characterize it sufficiently! It seems to me that an admission of the possibility and likelihood of error and of the need of making further tests under the same conditions to confirm the extraordinary claim put forth would be more laudable than this cool attempt at justification to which we are treated.

The probability is, however, that the Cahall Sales Department is not deceived by the extravagance of the claims and specious reasoning put forth in defense thereof. In these times something must be done to sell boilers besides adducing mere truisms, as all salesmen know that the number of satisfactory boilers on the market is sufficient to make it an increasingly difficut thing to effect a sale without claiming well-nigh impossible results and a superiority to all others.

I am afraid that certain "engineers of national repute" are prone to lend themselves to aiding this spirit of enterprise. Yours sincerely, George I. Rockwood.

62 Summer St., Worcester, Mass., April 3, 1897.

Magnetic Needle Disturbed by Electrical Charges in Glass Cover.

Sir: In a form of compass declinometer, modeled after a Russian instrument and intended for determining the magnetic declination or variation, some considerable effects on the needle of electrical charges in the glass cover have recently been noted. In this instrument the box is covered with a heavy glass plate, the under surface of which is only about one-eighth of an inch from the needle. In working with the instrument on some clear cold days in January (temperature near freezing), successive readings of the needle were found sometimes to differ several degrees, and the needle would occasionally rise and adhere to the glass. On one occasion rubbing the glass slightly with a dry finger violently disturbed the needle and threw it many degrees out of the meridian. This effect was not found to be entirely removed by touching the glass with the moistened finger, which is the remedy usually given by the books on surveying. When the glass and atmosphere are dry it is probable that the wet finger only removes the charge in its immediate vicinity.

Perhaps a more effective remedy would be to wipe the entire surface with a moistened cloth. A thin coat of glycerine over the surface of the glass has also been suggested. No disturbing effect of the glass on the needle was noted on damp and warmer days. This effect is undoubtedly dependent on the electrical condition of the atmosphere and the amount of moisture in it, and probably also on the electrical and hydroscopic properties of the glass. Of course when the atmosphere is moist, electrical charges will not be retained by the glass. The effective remedy adopted with the instrument referred to was the entire removal of the glass cover and the substitution of a metal cover which may be revolved, and which carries a small glass window through which the needle is observed. G. R. Putnam,

U. S. Coast and Geodetic Survey.

Washington, D. C., March 31, 1897.

Platforms for Elevated Trains in the New York Terminal Station of the Brooklyn Bridge.

Sir: In your issue of April 1 you say that the objection made in your editorial note of March 18 to the proposed arrangements for Brooklyn elevated trains at the New York terminal of the Brooklyn Bridge has been overcome by providing platforms on each side of one of the existing tail switches. If there were anything in this scheme, why not start all the passengers from there and put platforms on each side of the other tail switching track. Such a scheme would be nothing but an ordinary headhouse system. When trains are run on 45 seconds headway, or 90 seconds to each station track, each train must run into the tail switch and right out again without a stop. There can be no time to stop there and take passengers and then move forward and clear the junction in the rear of the station tracks in safety. (See the plan of tracks in your issue of Feb. 18.) It looks as if those who originated this idea, which looks so brilliant—on paper—would have to try again. Yours truly, J. C. C.

Brooklyn, N. Y., April 2, 1897.

(Our correspondent's criticism is well founded, as may be seen by a study of the plans of the bridge tracks which we have published. The problem is simply this: The incoming track and outgoing track both connect to a stub end track. Each train must run onto this stub-track far enough to clear the switch rail at the junction, and must then stop and run back on the other track and make this movement quickly enough so that the rear of the train will clear the junction before the head of the following train, 90 seconds behind it, comes along. If we allow 10 seconds as a minimum necessary interval at the junction for safety, the question is, is it possible for a train to run from a junction a distance of about 300 ft., stop, load with passengers, get under headway and move back 300 ft. again in 80 seconds? We do not think it possible.—Ed.)

Concerning the Rochester and the Liverpool Suspension Bridges.

Sir: Your issue of April 1 contains the descriptions of two wire cable suspension bridges over the Ohio River, remarkable for the fact that they convey very little information of the strength and engineering merit of the structures.

Take, for instance, the Rochester suspension bridge. In the plans and throughout the very copious narrative, there are, as if by intention, no data on the principal bridge members, no cross sections of towers, of stiffening trusses, floor construction, no center deflection of cable, or size of anchorages, dead load, or other indispensable definite details required by an engineer for forming a judgment. The size of the cables and the assumed live load are the only data mentioned; taking them in combination with a probable minimum suspended dead load of 2,240 lbs. per lin. ft., estimated on the scanty basis of commercial bridge work of that cheap character, it would give a factor of safety in the cables of about 2 7-10. If, as alleged, the bridge is also proportioned for a concentrated load of street cars, weighing together when meeting, 60 tons, then the factor of safety is still less, a fact of which the public ought to take notice.

In one place the article says that a bending of the towers produced somewhere a unit strain of 43,155 lbs., which in some indefinite way is claimed to be reduced to 35,000 lbs. per sq. in. Inasmuch as the towers in that bridge are warning examples of "how not to do it," namely, designed without any efficient web bracing, and therefore incapable of resisting shearing and chord strains from bending, it is difficult to see by what method of "figuring," to use his own term, the builder of that bridge arrives at his bending stresses, or how he prepared a strain sheet from which an opinion might be obtained of its stability under vertical loads, or against wind pressure. It does seem that in the case of one of those not infrequent strong winds, peculiar to the upper Ohio, the safety factor of that bridge may approach dangerously near to zero. The curious jargon of the description, the unprofessional want of elementary knowledge it betrays of the theory of suspension bridges, and of the fact that fixed saddle bearings have been used long ago, do not justify the claim of the chief engineer to alleged original discoveries, doctrines and experience in suspension bridge construction.

The article on the East Liverpool bridge is also very incomplete in the essential data requisite to form an opinion on the strength and merit of that structure, which has to be given credit, however, for better designed towers and stiffening trusses. The necessity of roller saddles on top of the slim towers is not explained, and the adjustment of the wire strands on the anchorage pins with molten babbit metal seems to be a practice for which a good reason should be given. Babbit metal is used for journal bearings with pressures of 1,000 to 2,000 lbs. per sq. in.; whereas, the pressure on the anchor pins is probably eight to ten times that amount, and the question arises whether the babbit metal will resist the pin pressures as well, or half as well, as iron or steel.

New York, April 5, 1897. A Member A. S. C. E.

The Nicaragua Canal Again.

Sir: The left-handed blow of Mr. Holcombe, delivered against the patriotic position of your paper on the Nicaragua Canal question is credited to this state, therefore it is fitting that an answer emanate from the same locality and from one who ranks Mr. Holcombe as a reader of your valued journal by three years as per his own count.

People who are interested in the general welfare of this nation heartily endorse the stand you assume on this great international and industrial problem.

The original concession for this great oceanic waterway was made direct to the United States. The treaty was

ratified by the Nicaraguan government. The United States had two years in which to ratify it; but this was never done, and in lieu thereof came the Maritime Canal Co. asking and receiving as a private enterprise the same valuable franchise. Previously the preliminary surveys had been made at the expense of the U. S. government, and all the machinery of diplomacy had been exerted to put a treaty in shape, when the great bubble of patriotic (?) greed swells up and whispers, "It is not meet for a great nation to withhold rich crumbs from her citizen." Then history repeats itself.

Study the early days of the Pacific Railways! Then, as now, the conception, the unrewarded labor and wealth of others was utilized. Asa Whitney dissipated his ample fortune to promote the welfare of an unappreciative people; others garnered the reward.

In the case of the Nicaragua Canal there was added to these early notes of examination and survey, some details, more surveys, a little work, plans and profiles which, according to the canal company's own showing, cost $1,000,000 in cash. They claim to have issued stock for concessions and claim the property has cost $13,000,000. Now they graciously offer to hypothecate these holdings of questionable value upon which to raise $100,000,000 from a too long suffering and paternal Uncle Sam.

There is an intuitive suspicion that unfair methods were used to delay the ratification of the original treaty as well as in the downfall of Asa Whitney.

This is certain, with the control of the Pacific Mail Steamship Co., the Nicaragua Canal concessions and the Pacific Railways these same friends of Mr. Holcombe had this coast in their grip. They exacted a tribute from California and Oregon which would put the landlords of Ireland to shame. It is safe to assume that this interest has been a "dog in the manger" thus far. Until recently it has not been to their interest to build the canal at all. But now competing railway lines, not in the interest of our friend's clients, have changed the conditions. Now, our friend's friends would be willing to build and operate the canal provided Uncle Sam will put up the "stuff."

The Pacific Coast is intensely interested in this Canal, for it must be to us as the Erie Canal is to New York. As a people we are loth to see it in the hands of those who, by high toll, favoritism or unjust discrimination can control it for all the traffic will allow.

As an illustration. On the Willamette River in Oregon there are some locks controlling a grand natural waterway. Twenty-two years ago these locks received from the state treasury $200,000 to aid in their construction. Now, the interest owning the locks also owns and operates a line of steamers. The tolls are very high to all alike. To one line of boats it is a matter of bookkeeping, a transfer from one pocket to another. To competing boats it is so much from their profits. To the patrons, to the farmer and consumer, it is a tax of stern reality.

At a Chamber of Commerce meeting at Portland two years ago, at which Oregon's two Senators were present, it was clearly indicated that the prosperity of this coast demanded that the U. S. government build and control this canal.

If it puts up the money why should it not own and operate it for the benefit of all the people alike?

"He who would serve himself the best must serve his country's interests first."—Jefferson. I. K.

Portland, Oregon, March 26, 1897.

Eccentric Loads on Steel Columns.

Sir: I have read with great satisfaction your able criticism of the Gray column and also the answer made by Mr. Gray. I don't want to take much of your valuable space, but I would like to have the following point fully demonstrated by Mr. Gray, for his handbook is short on the question:

If one of his columns is loaded on one or two sides only, will the load distribute itself evenly to the four pairs of angles at the point of connection?

I suggest to Mr. Gray to make experiments on his columns as they are used in general building work. The tests made by the Keystone Bridge Co. were of an ideal character as far as the method of loading was concerned, and this is rarely achieved in practice. I believe that the experiments referred to would have given very nearly the same results, if after milling the columns, the tie plates had been removed and the four pairs of angles tested in groups as milled.

I am decidedly of the opinion that columns for building work should be designed to resist transverse forces, that the connections between the different parts which make up the column should be such as would be considered good practice for beams or girders and that constructions whose efficiency cannot be demonstrated by ordinary methods should be avoided.

Mr. Gray's able arguments on bicycle frames and against continued web columns are too scientific to be well understood at sight by any well-known designers of structural work; those who have charge of some such noted works as the Park Row building, for instance, would do well to study the question. Mr. Gray states that eccentric loading in columns can take care of itself if each stack of columns is continuous from the bottom to the top of a building and if the entire skeleton is absolutely independent of walls, floors or partitions. Can Mr. Gray prove that too? Yours truly, Harold MacMaster, C. E.

Trenton, N. J., March 13, 1897.

Sir: In your criticism of the Gray column in your issue of Feb. 25, it seems to the writer that the weak points of this column are not shown with sufficient clearness. The essential idea of the design of the Gray and similar columns seems to be that if the component members of a column are braced so as to prevent buckling, then the column shears may be neglected. Fig. 1 shows the most common method of applying loads upon the interior columns of a building. Fig. 2 shows the common method with long span of girder. Fig. 3 shows a method that occurs but rarely, but it does occur in a few instances in at least one existing building using the Gray column. In Fig. 1 it will be seen that column members (1) and (3) carry twice as much as column members (2) and (4), while in Figs. 3, (1) and (3) carry the entire load while (2) and (4) carry nothing. Now it must be borne in mind that no provisions are made for resisting column shears. Assuming the floor to be uniformly loaded, none of the figures represent cases of eccentric loading.

On p. 1 of his manual Mr. Gray gives the following formula for computing the safe load to be carried by a Gray column:

$$\text{Safe load per sq. in.} = 17{,}100 - 57\,\frac{l}{r}$$

Now this is purely an empirical formula based upon experiments with columns in which provision was made for resisting column shears. On p. 126 of Carnegie's Pocket Book Mr. Strobel states that this formula gives an average factor of safety for Z-bar columns (the old form, not the "Standard dimension column) of about 4½. On pp. 48 to 51 of Gray's Manual is a record of tests upon full size Gray columns. The following table shows the safe load as given by the formula and the resulting factor of safety:

No. of col.	Breaking strain, lbs. per sq. in.	Working strain, lbs. per sq. in., by the formula, $17{,}100 - 57\,\frac{l}{r}$	Factor of safety.
1	40,020	15,390	2.60
2	39,340	"	2.56
3	38,800	"	2.53
4	40,020	"	2.60

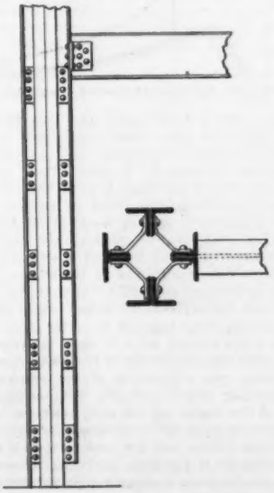
It is to be observed that in all the above experiments the four members of the columns were equally loaded. The writer believes that no experiments have been made with the breaking load distributed upon the different column members as shown in Figs. 1, 2 and 3. As the Carnegie Steel Co. have recently brought out a Z-bar column based upon the same principles as the Gray column, the writer would take the liberty to suggest that they make the additional experiments above suggested. Yours, Architectural Engineer.

Chicago, March 15, 1897.

(Proofs of the above letters were submitted to Mr. Gray in accordance with our usual rule, and we append his reply.—Ed.)

Sir: The proofs of the articles by Mr. McMaster headed "Eccentric Loads on Steel Columns" and the anonymous one on the same subject were forwarded to me here.

In reply to their questions and criticism, the enclosed drawing of an ordinary single-story length of column, loaded



on one side only, is submitted; with the pair of angles which support the load directly, cut off below the bottom set of tie plates.

Their contention that "Gray columns" neither provide for shears nor bending, is purely assumption without investigation or proof, and I contend that both are provided for, as well as direct loads, and the sketch, which is a typical one, illustrates as clearly as possible the manner of so doing. Very truly yours, J. H. Gray.

New York Life Building, Chicago, April 2, 1897.

Notes and Queries.

P. R. Ismoid asks if the well-known prismoidal formula is applicable for determining the volume of a solid whose base is a horizontal plane figure and whose top is also a horizontal plane but of different form. The sides of the figure are in many cases warped surfaces.

As we understand the prismoidal formula, it is applicable for determining the dimensions of any solid bounded by two parallel plane figures if all parts of the surfaces connecting these two parallel plane figures are generated by a straight line, moved in contact with the periphery of these figures. Or, to put it in another form, if all parts of the periphery of the section midway between the end sections can be touched by a straight line in contact with the periphery of the end sections, the solid can be computed by the prismoidal formula. For an explanation of the prismoidal formula see Henck's field book, p. 141.

RECENT DEVELOPMENTS IN GAS ENGINES.

By Dugald Clerk, Assoc. M. Inst. C. E.

(Concluded from p. 208—with two-page engraving.)

Many economical and well-designed engines of the Otto cycle are now built by various firms of manufacturers, exhibiting only small variations in mechanical detail. The engines made by Messrs. Andrew & Co., of Reddish, are well designed, and as may be seen from Figs. 19 and 21, high economy is attained. Messrs. Andrew have built very large engines for mill purposes, using Dowson gas, and in Fig. 23 on the inset sheet is shown an engine of 400 I.HP. built by them and erected at Messrs. Spicer's works, at Godalming. This is at present one of the largest gas engines in the world. Its arrangement is novel and interesting. Two cylinders are mounted in tandem on a bedplate. To avoid passing a piston-rod through a combustion space, the pistons are connected by piston-rods, crossheads, and side rods; both connect thus to a single crankshaft by a common connecting rod. Each cylinder works on the Otto cycle, but the valves are timed to make the explosions alternately. In this manner an impulse is obtained for every revolution of the fly-wheel. Fig. 24, on the inset, illustrates the arrangement of one of Messrs. Andrew's engines of moderate dimensions, and Fig. 25 is a section of their combined timing and starting-valve. This engine resembles, as do most gas-engines, the Crossley engine, in having separate inlet and exhaust passages leading from the combustion space.

In the Author's opinion, engineers have not sufficiently recognized the importance of limiting port surface to the

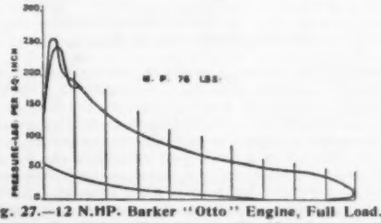


Fig. 27.—12 N.HP. Barker "Otto" Engine, Full Load.
Diameter of cylinder, 10 inches; stroke, 18 inches; revolutions per minute, 180; I. HP., 24.4 at 76 lbs. per square inch mean pressure; gas consumption per I. HP. per hour, 18 cubic feet; gas consumption per B. HP. per hour, 21.5 cubic feet; maximum pressure of explosion, 244 lbs. per square inch; pressure of compression, 55 lbs. per square inch.

utmost. By so doing, the cooling surface in contact with the intensely hot gases is minimised. By reducing or abolishing passages leading into the combustion space, less heat is lost during the explosion period. Messrs. T. B. Barker & Co. have kept this point well in mind while designing the Otto cycle engine illustrated at Fig. 26. The

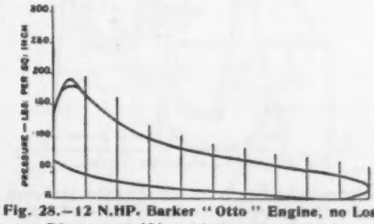


Fig. 28.—12 N.HP. Barker "Otto" Engine, no Load.
Diagram at 104 revolutions per minute.

valves are placed in the cylinder in such manner that passage or port surface is avoided. The inlet-valve is within the cylinder, and the exhaust-valve is placed close beside it. The engine illustrated is of 12 HP. nominal, and the diagrams, Figs. 27 and 28, show high economy.

An engine of Messrs. Barker's construction, tested by Mr. J. M. Morrison, at the Saltley gas works of the Birmingham Corporation at the beginning of 1894, gave the highest economical results, Fig. 29, attained within the

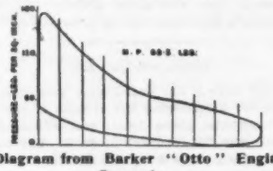


Fig. 29.—Diagram from Barker "Otto" Engine, Saltley Gasworks.

Diameter of cylinder, 12 inches; stroke, 20 inches; revolutions per minute, 156; I. HP., 24.3 at 67 lbs. mean pressure (average of a number of cards); Saltley gas; consumption per I. HP. per hour, 17.2 cubic feet; B. HP., 19.9; consumption per B. HP. per hour, 21.3 cubic feet; maximum pressure of explosion, 195 lbs. per square inch; pressure of compression, 50 lbs. per square inch.

author's knowledge by any engine previous to the Crossley Scavenging engine. From this it appears that the engine consumed, on an average of four tests, only 21.3 cubic feet of gas per brake HP. per hour, or 17.2 cubic feet per I. HP. hour, which is an extraordinary low consumption for an engine using Birmingham gas. The compression was only 50 lbs. per sq. in., so that much of the high efficiency undoubtedly arises from the great diminution of port surface within the cylinder.

Self-Starting Gear.—Before leaving the Otto cycle engines, it may be advisable to describe briefly the starting gears which are now used for such engines. The great increase in the power of the engines manufactured has made it imperative to dispense with the old manual method of starting gas engines.

The first starting gear introduced in Great Britain was invented by the author, and it was applied to the Clerk impulse-every-revolution engine in 1883; it is fully described in his book.* The starter required to store up air or a mixture of gas and air under compression, which was found to involve expensive arrangements; and, although the gear was quite satisfactory in action, the first cost was too high. The starting gear now used more extensively than any other is also an invention of the author; and the Clerk starter is now applied by Messrs. Crossley, who have acquired the patent, to all engines which require a starter. Fig. 30 is a diagramatic section

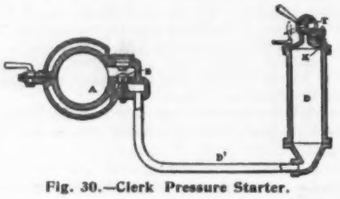


Fig. 30.—Clerk Pressure Starter.

illustrating its action. A is the gas engine cylinder, B a check-valve opening into the exhaust-port, D a chamber connected by pipe D^1 with the valve B, and T is an igniting valve. K is a port leading to a charging pump.

The object of the device is to fill the combustion space of the engine with a compressed mixture of gas and air, and then to explode the compressed mixture, thus starting the engine by means of a high pressure explosion. To start, the crank is placed off the centre; the pump is operated by hand to fill the chanmber D, pipe D^1 and cylinder A, with gas and air mixture at atmospheric pressure, so that no resistance is experienced in operating the pump. The igniter T is then operated, and the mixture in the chamber D ignites near T; the flame, as it spreads through the chamber, forces the unburned mixture before it into pipe D^1, through the valve B into the cylinder A; so that when the flame arrives at the valve B, it has swept before it into the cylinder all the unburned mixture. When the flame passes the valve B it ignites

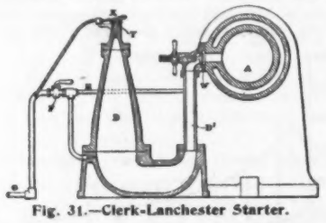


Fig. 31.—Clerk-Lanchester Starter.

the compressed mixture in the cylinder; and, producing a high-pressure explosion, the engine is started off with an ample margin of power to overcome the friction of belting and shafting.

In conjunction with Mr. F. W. Lanchester, the author introduced the starting gear illustrated in Fig. 31, which

*"The Gas Engine," London, Longmans, Green & Co., 1886, p. 239.

is known as the Clerk-Lanchester starter. In this arrangement a Lanchester igniting valve Y is used, and the pump for charging the chamber D is dispensed with. When the engine is stopping, the valve W is opened and air is thus pulled through the chamber D by way of the valve Y at every suction stroke. The chamber D, pipe D^1 and cylinder A thus became filled with pure air at atmospheric pressure.

When the engine is to be started, the gas-cock F is opened, and gas flows from the main at G into the chamber D, and at H into the pipe D^1, a cock on the cylinder is opened to allow flow into the cylinder or the exhaust-valve is held slightly open; the flame X burns across the valve Y, and after a few seconds the mixture of gas and air escapes through Y and burns in the air.. The cock F is then closed, and the flame shoots back past the valve Y, and so ignites the mixture within D, thus closing the valve Y. The flame then proceeds along D, D^1 into the

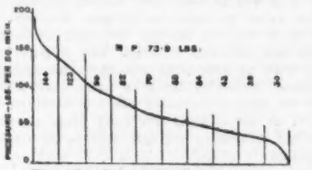


Fig. 32.—Clerk Starter Diagram.

cylinder A, firing the mixture it has compressed, and the engine is thus started by a compression explosion. Fig. 32 is a starting diagram obtained from this arrangement. From this it will be observed that a maximum pressure of over 200 lbs. per sq. in., and a mean pressure of 74 lbs. per sq. in. is easily attained for a starting explosion. Fig. 33 is a cross section of the Lanchester low-pressure

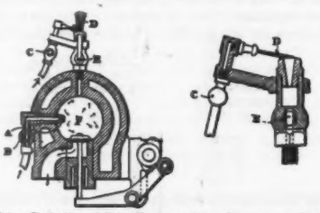


Fig. 33.—Details of Lanchester Low Pressure Starter.

Nozzle, A; cock, B; cock, C; master-flame, D; cock, E; cylinder, F.

The gas is allowed to flow into the air-filled explosion space in the cylinder F and flows out mixed with air through the cock E, where it is ignited by the master-flame D. When the flame assumes a certain color, indicating the richness of mixture in the cylinder, the gas-cock B is closed and the flame rushes back into the cylinder, thus giving an impulse.

starter which is also largely used, and Fig. 34 shows the starting diagrams.

The Clerk and the Lanchester starters may be taken as typical of the modern starters, but every manufacturer now provides a starter of some kind. Messrs. Barker and Messrs. Robey & Co. use the Lanchester starter. Messrs. Andrews also adopt a similar low-pressure starter. Messrs. Tangye start by pumping a compressed charge into the

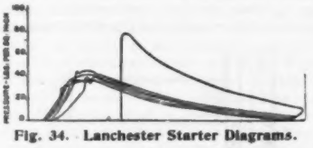


Fig. 34. Lanchester Starter Diagrams.

engine cylinder by a hand pump, and then firing; while Messrs. Fielding and Platt admit compressed air from a reservoir to gas filling the cylinder, and then ignite.

Impulse-Every-Revolution Engines.—The late Prof. Faraday has well said that more is to be learned from the failure of an experiment than from its success; a statement which is as true in engineering as in physics. Smooth success is not conducive to rigorous investigation. So long as a machine performs its work easily and satisfactorily, there is little inclination to investigate in it the precise balance of cause and effect. Accordingly, it is natural to find that the explanations of gas-engine phenomena come mostly from those engaged on cycles other than the Otto. From a mechanical point of view, the Otto cycle is a very imperfect one, involving as it does at most an impulse for every two revolutions of the crank-shaft for each single-acting power cylinder. The mechanical imperfections of the engine up till now, however, have been more than compensated for by the simplicity due to the single cylinder and piston, and the readiness with which the practical conditions of charging, exploding, expanding and exhausting can be made to comply with the requirements of economical working.

At first it seems to many engineers a simple matter to design a compression gas-engine capable of giving an impulse at every revolution for each single-acting motor cylinder. The problem is in reality one of the most difficult in the whole range of engineering, and, although it has been the subject of much continuous effort, no solution has yet been found which satisfies simultaneously the commercial conditions of the problem for large and for small engines. There is now no difficulty in building impulse-every-revolution gas-engines which will give the highest possible economy, and work perfectly; but such engines, so far, cost more for small powers than Otto cycle engines of like power. For powers up to about 20-HP., it appears probable that the Otto engines will continue to monopolize the field; but the demand for larger engines is increasing so rapidly, that, in the author's opinion, the impulse-every-revolution engine will now come into use again, and in time displace the Otto cycle for large powers.

It has always been observed that before a satisfactory solution of any important engineering problem is attained, many proposals or attempts are made by able inventors; and, although some of them attain partial success, yet, as a rule, years elapse, one inventor succeeding another, and carrying the subject a little further, before sufficient knowledge is accumulated to make the matter commercially successful. The gas-engine has a history of this kind, which the following table will clearly indicate:

Year.	Inventor.	Nature of Engine.
1794	Robert Street	Explos. without comprsn.
1823, 1826	Samuel Brown	Vacuum gas-engine.
1833	W. L. Wright	Explos. without comprsn.
1838	William Barnett	Explos. with compression.
1855	A. V. Newton	Explos. without comprsn. Tube igniter.
1857	Barsanti & Matteucci	Atmospheric engine.
1860	Lenoir	Explos., non-compression.
1862	Beau de Rochas	Comprsn-eng., Otto cycle.
1866	Otto and Langen	Atmospheric.
1876	Otto	Modern Otto engine.

The table only gives the names of a few of the leading inventors; many other propositions occur among English patents.

Street had the germ of the non-compression engine in 1794; Wright in 1833 gave it more perfect expression; but it was never successfully reduced to practice till Lenoir's engine in 1860. In 1862 a French engineer actually proposed the Otto cycle gas-engine and discussed carefully the conditions of its success; but left it to be independently discovered and reduced to practice by Otto in 1876. Otto began his long struggle with gas-engine difficulties in 1854, and achieved a partial success in 1867 with the Otto and Langen atmospheric engine, which itself was first proposed by Barsanti and Matteucci in 1857. He worked and studied until, in 1876, he invented the famous Otto engine which has proved the turning-point in gas-motors. He had thus labored hard at his subject for twenty-two years before real success crowned his efforts.

It has often occurred to the author how much more rapidly engineering science would advance if inventors placed on record some description of their experimental failures as well as accounts of their successes; as one inventor succeeds another, each one goes over again, to a great extent, the ground traversed by his predecessor, and discovers for himself the difficulties which overcame him. As one who has devoted many years of persistent effort to the development of the impulse-every-revolution engine, a short account will first be given by the Author of the different engines built by him, with a statement of the difficulties peculiar to each.

The first engine built by the Author is shown in Fig. 35 on the inset sheet. It was designed by him early in 1878. There were two cylinders, each of 6 ins. diameter by 8 ins. stroke; one being a pump cylinder, the other a motor cylinder. The pump crank followed the motor crank at right angles, and it pumped a mixture of gas and air into an intermediate reservoir through a check-valve. From this reservoir the mixture was supplied to the motor cylinder by means of a slide-valve. The mixture was compressed in the reservoir to a pressure of 70 lbs. per sq. in. above that of the atmosphere. The motor piston moved back to the end of the cylinder, leaving only a mechanical clearance of about ¾-in. and the exhaust-valve was shut a little early in order to cushion the piston as is done in the steam-engine. The motor piston moved forward from the end of its stroke about 2 ins., taking in the compressed mixture from the reservoir; the slide-valve then cut off the supply and ignition was effected by an incandescent platinum cage carried in the slide. This engine was exhibited at the Royal Agricultural Society show at Kilburn in 1879, and was, the Author believes, the first explosion compression gas-engine ever built which gave an impulse for each revolution of the crank-shaft. The Author's object in the design was to utilize high compressions, and to obtain one impulse for every forward stroke of the motor piston. The engine at full power developed 4 B.HP.

Two great difficulties were encountered after the minor difficulties, requiring the invention of special igniting, governing and starting gear, were overcome; (1) back ignition into the compression reservoir; (2) shock in the motor cylinder. The difficulty of ignition spreading from the motor cylinder to the compression reservoir was serious, and was not completely overcome. The reservoir and the valves were made amply strong to stand the maximum pressure possible on explosion of the compressed contents; but as the reservoir contained about twelve charges from the pump, it was found that with full load

on the engine it pulled up upon back ignition before the burned gases were cleared out of the reservoir. Back ignition occurred very seldom; but when it did it involved the stoppage of the engine. Various modifications were made to overcome this difficulty and that arising from shock, and the latter difficulty was obviated. The shock was due to the too rapid ignition of the contents of motor cylinder, and was avoided by changing the shape of the compression space. This engine was capable of running at high speed, the igniter being very powerful. The incandescent platinum cage was so arranged that when once heated the platinum received heat enough from the consecutive explosions to maintain it in an incandescent state. As many as 300 revolutions per minute have been attained with this engine with perfectly consecutive ignitions.

The next engine built by the Author is shown in plan and side elevation at Fig 36, on the inset sheet. In it the pump does not compress its contents to the pressure of compression, but simply forces the mixed gas and air into the cylinder while the motor piston is crossing the exhaust ports at the end of its stroke; the motor piston on its return stroke compresses the charge of gas and air into a clearance space at the end of the cylinder, when the compressed mixture is ignited, propelling the motor piston forward at every revolution of the crank-shaft. The first engine of this type was designed by the Author in 1880, and was built at the end of that year. The first engine exhibited was shown at the Paris Exhibition of 1881. Several hundreds of these engines were built by Messrs. L. Sterne & Co., at Glasgow, under the Author's supervision, in sizes ranging from 3 to 30 I.HP. This Clerk engine has been extensively followed in Great Britain and on the Continent, and several thousands of engines of this type have been put to work.

The results were specially satisfactory with the larger sizes, and Fig. 37 is a diagram, with the particulars of the

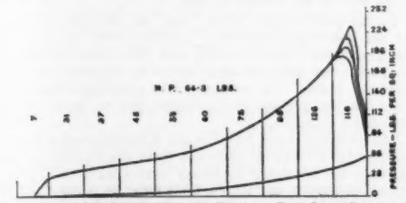


Fig. 37.—12 N.HP. Clerk 1881 Engine, Full Load Diagram.

Diameter of cylinder, 9 inches; stroke, 20 inches; revolutions per minute, 132; I. HP., 27.46; consumption per I. HP. per hour, 20.39 cubic feet; consumption running light per hour, 90 cubic feet; B. HP., 23.31; consumption per B. HP. per hour, 24.12 cubic feet; mean pressure, 64.8 lbs. per square inch; maximum pressure, 230 lbs. per square inch; pressure of compression, 57 lbs. per square inch (Glasgow gas).

test marked under it, taken at Glasgow in 1885. The economy in gas at that time for the larger sizes was quite equal to that obtained with the best Otto engines. The smaller sizes, however, were less satisfactory. With engines of 20 HP. excellent results can be obtained, but with an engine developing only 4 HP. the consumption of gas was somewhat high.

The great difficulty of this type of engine was found to be in governing economically at light loads or no load. The difficulty was met to some extent by the use of the Garret governing gear, but at light loads this engine was always somewhat higher in gas consumption than the Otto. This fact, combined with the higher consumption of the smaller engines, placed it at a disadvantage in the market, and led to its abandonment in favor of the Otto cycle when makers were free to use the latter. The engine ran very steadily and satisfactorily when properly proportioned, but great care had to be exercised in determining the proportions of pump and motor, and the shape of the passages and compression space, in order

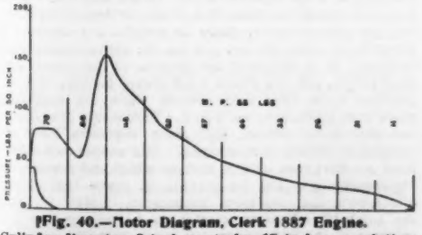


Fig. 40.—Motor Diagram, Clerk 1887 Engine.

Cylinder diameter, 9 inches; stroke, 15 inches; revolutions per minute, 140; I. HP., 10.71 at 54.9 lbs. per square inch mean pressure (average of several cards); gas consumption per I. HP. per hour, 20.1 cubic feet; B. HP., 8.96; gas consumption per B. HP. per hour, 24.1 cubic feet (Birmingham gas).

to secure the uniform discharge of the exhaust gases. Any error in these particulars led to the discharge of unburned gas at the exhaust ports; and this was the reason why better results were obtained with large engines than with small ones. In the smaller engines it was hardly possible to avoid the discharge of some unburned gas at the exhaust-ports during the operation of charging.

In 1886 the author built another engine at Birmingham of the same type as the 1878 engine, but differing from it in having no reservoir between the pump and the motor. This engine is shown in Fig. 38, on the inset sheet; a sectional plan through the cylinder, and an end view in part section, showing the arrangement of the levers, being given in Fig. 39. A motor diagram and a pump diagram are given in Figs. 40 and 41.

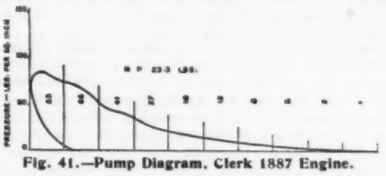


Fig. 41.—Pump Diagram, Clerk 1887 Engine.

Fig. 42 shows the relative positions of the motor and pump-cranks at different positions and at the moment of firing. This engine gave very economical results, and its running was satisfactory when the adjustments of the valves were accurately maintained. The difficulty of back ignition into the pump was overcome by diminishing the passage between motor and pump to the smallest possible volume. When back ignition did occur, the engine

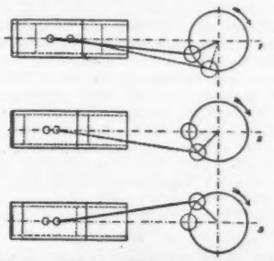


Fig. 42.—Diagram Showing Positions of Motor and Pump, Clerk 1887 Engine.

The motor-crank and connecting-rod are shown in full lines and the pump-crank and rod in dotted lines; 1 is the position when the valve opens between motor and pump; 2 when the motor-piston is full in; and 3 shows the pump-piston full in and the motor-piston in the igniting position.

was not materially affected, as the pump at once took in a new charge of gas and air, and, after compressing it, delivered into the motor cylinder as the piston moved on its forward stroke. The motor piston moved on to the end of the stroke, leaving only mechanical clearance, and so discharged the whole of the exhaust products.

The governing was accomplished by opening a special valve from the pump-cylinder to a reservoir of considerable capacity, closing the valve communicating between the pump and motor-cylinders, and holding open the exhaust-valve during the exhausting and charging strokes. The effect of these operations was to prevent the transfer of a charge from pump to motor; the pump-piston acting to compress and expand the charge to and from the governing reservoir, while the motor-piston alternately discharged the exhaust gases into the exhaust-pipe, and took them back to the motor-cylinder. The governing was economical.

The engine is too complex to compete with advantage with small engines, but is well adapted for large powers. It admits of any required compression and any required expansion of the gases after ignition. But, like large mill steam-engines of the Corliss type, it required careful handling and attention. It is not suited for the rough work and unskilled attention which is given to small gas-engines.

To secure the best results, it is necessary that the ignition should follow the closing of the inlet-valve from the pump to the motor with extreme rapidity, as a short delay in firing causes considerable loss of power. This is shown by Fig. 43, where the ignition has occurred too late.

A considerable loss of power is thus caused by firing at a low instead of at a high compression. To obtain the

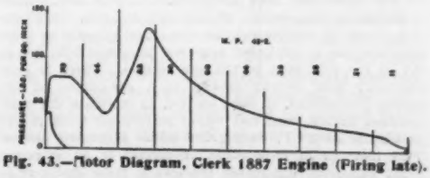


Fig. 43.—Motor Diagram, Clerk 1887 Engine (Firing late).

best results from this type of engine, the stroke should be long in relation to the diameter of the cylinder. With a large engine with a cylinder of say 24 ins. diameter, a stroke of 4 ft. would be desirable; such an engine could readily be designed to give consumption equivalent to 11 cu. ft. of Birmingham gas per I.HP. hour. Eighty revolutions per minute would be a suitable speed for it. The engine would be arranged to give an impulse every revolution when light as well as loaded. This type of engine has also been arranged by the Author to have a considerable clearance space at the end of the cylinder, which space should be swept out by pure air. With such a space, the difficulties of the engine are considerably diminished.

In 1889 the Author designed the engine illustrated in Fig. 44 on the inset sheet, and Fig. 45; and a small example of the type was constructed at Birmingham in 1889 for experimental purposes. Two pistons are employed in one cylinder; one, the trunk-piston, is the motor-piston, and the second is the charging and exhaust-expelling pis-

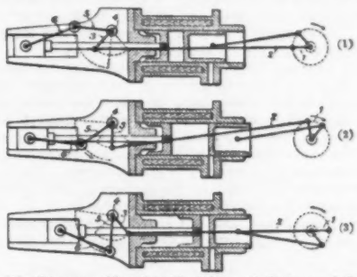


Fig. 45.—Diagram Showing Positions of Motor and Pump, Clerk 1887 Engine.

ton. The second is operated by a piston-rod passing through a cover at the back of the engine cylinder; this rod is attached to a cross-head working in guides; operated by a separate crank (1), connecting rod (2), lever (3), rocking-shaft (4), and toggle-links (5) and (6). The motion is so devised that when the motor-piston is out and crossing the exhaust-port, the charging-piston moves out and discharges the products of combustion from the cylinder by the front exhaust-port. At the same time it takes into the cylinder a charge of gas and air on the other side. The two pistons then move back together and the charge is compressed; after a time the charge passes from the back of the charging-piston to the front, and so occupies the space between the two pistons, and is ignited when the motor-piston is full in. The motor-piston then moves out under the pressure of explosion while the back piston remains practically stationary. This pause is brought about by the toggle-links crossing their centre, and it is sufficiently prolonged to enable the motor-piston to practically complete its stroke before the back piston begins to move.

In the first position, Fig. 45, the engine is exhibited as when the mixture is ignited. In the second, the motor-piston is just overrunning the exhaust-port and the charging-piston about to move out. In the third, the piston has returned, closing the exhaust-port, and the charging piston is fully out, having taken in its charge at the back of the piston and discharged the exhaust at the front; the first position is then repeated, when the charge is compressed and ready to ignite. This engine is, in the Author's opinion, well adapted for both moderate and large powers. It is simple and avoids all the difficulties of the impulse-every-revolution engines. It is capable of the highest economy possible in a gas-engine.

Before leaving this part of the subject it is necessary to shortly describe the work of Mr. James Atkinson, who has made a very determined effort to conquer the difficulties attending this type of engine. Mr. Atkinson's first gas-engine patent is dated 1880, but his first compression gas-engine was exhibited in 1884. It was designed much on the lines of the Author's 1878 engine, and the difficulties encountered by both were similar. Mr. Atkinson's first original solution of the difficulty of obtaining an impulse at every revolution in an explosion compression gas-engine was made in 1885, a vertical section of the engine being shown in Fig. 46, on the inset sheet. Fig.

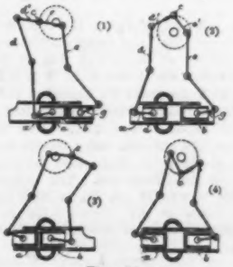


Fig. 47.

47 shows the various positions of the two pistons which perform the operations of the cycle.

Two pistons a and b are connected with a common crank-pin c by levers d e, and rods d' e'; short links x and g connect the lower ends of the levers with the pistons. In the first position the exhaust is completed. In the second the piston a has moved away from the

other one to take in the charge of gas and air. The piston b, in the next position, has followed a and compressed the charge, while in the last the piston b has moved out and expanded the gases after explosion. The engine is very ingenious, and performs all the operations of charging, compressing, exploding, expanding, and exhausting, in one revolution of the crank-shaft. A consumption of 25 cu. ft. of London gas per brake HP. hour at full power was claimed for this engine by its designer. It was found, however, that the linkage was troublesome mechanically, and that the consumption of gas when running without load was high. The engine was capable of expanding the hot gases down to a low pressure, but a great disadvantage was found in the shallow compression space in relation to the diameter of the cylinder. A shallow compression space approximates too closely to an ideal condenser or cooler, and so an engine with such a space may lose more than is compensated for by the extra expansion.

Mr. Atkinson replaced this engine, which he called the "Differential gas-engine," by a very ingenious engine, Fig. 48, in the inset sheet, to which the name of the "Cycle Engine" was given. The engine marked a great advance on the differential engine, and in its expanding the hot gases a step was made in advance of any engine up to 1888 in point of economy of gas consumed. One of these engines was submitted to the Society of Arts in competition with the Crossley engine mentioned in the earlier part of the Paper, and was found more economical than the latter. Fig. 49 shows four positions of the piston and

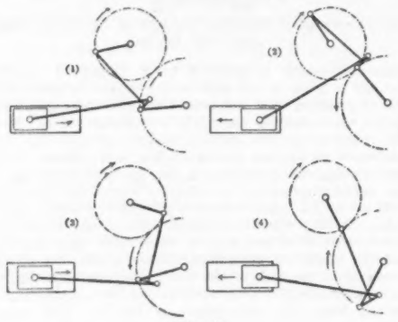


Fig. 49.

other parts. By following the movements it will be found that the whole of the operations of the Otto cycle are performed simultaneously with the expansion of the whole of the exhaust gases by one piston connected with the crank-shaft by a peculiar linkage. The engine is fully described in the Report of the Judges for the Society of Arts.[1]

It is true that in this engine an impulse was given to the crank-shaft for every revolution, but notwithstanding this the piston made four single strokes for each cycle of operation, so that, as far as the piston was concerned, the Otto cycle was followed. The economy was gained by expanding to a greater volume than that existing before the compression of the gases.

Fig. 50 is a diagram reproduced from the Society of

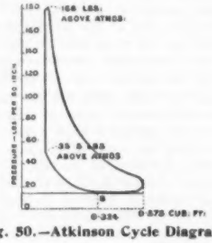


Fig. 50.—Atkinson Cycle Diagram.

Arts report, page 18, showing the Atkinson diagram. It will be observed that the compression pressure is only some 35.5 lbs. per sq. in. above that of the atmosphere, but while the volume at the point B is 0.324 cu. ft., the volume to which the gases are expanded before exhausting is 0.575 cu. ft. If the Atkinson engine had worked in the same manner as an Otto engine, using the same compression, then the exhaust valve would have discharged the cylinder at the point B, so that the remainder of the pressure would have been lost. The volume of the compression space was 0.118 cu. ft., so that the ratio of the compression space to the volume 0.324 is as 1 to 2.74. The theoretical efficiency of this part of the diagram would therefore be

$$E = 1 - \left(\frac{1}{2.74}\right)^{0.408} = 0.33.$$

This efficiency is that of the lowest Otto result given on page 206 and the actual efficiency to be expected would be 0.15. The Society of Arts trials showed the actual efficiency to be 0.205, so that the difference is due to the extra expansion. The consumption of gas in London was 18.82 cu. ft. per I.HP. hour, by far the lowest consumption of that period.

The high-piston-speed of the "cycle" engine during its expansion stroke, and the great expansion, both tended towards economy; but the relatively shallow combustion space made it desirable to keep down the pressure of compression, so the results which could have been obtained with high compressions and the same relative expansion were not produced. The engine had mechanical defects also which led to its ultimate withdrawal. The piston-speed was very high, and the joints were too numerous to secure complete commercial success.

The Author has rapidly traversed the leading points connected with Otto cycle and impulse-every-revolution engines. He proposes now to consider the modifications which may still be made in the indicator diagram of the gas-engine to further increase its heat efficiency. In this, the Otto cycle will be referred to, but it is to be remembered that the impulse-every-revolution engines may be arranged to produce any of the results brought about by the Otto engine. It has been pointed out that the actual indicated efficiency of a gas-engine increases with the theoretical efficiency, and that the actual efficiency varies between 45% and 58% of the theoretical efficiency. The indicated efficiency also increases with the dimensions of the engine, other things being similar, when the ratio of compression space (and therefore the theoretical efficiency) remains constant. Thus an engine with a 9½-in. cylinder and 18 ins. stroke, having a theoretical efficiency of .40, gave an indicated efficiency of 0.19 or 0.47 of that theoretically attainable. Referring to a careful test of a 100-HP. double cylinder Otto engine made in Philadelphia by Mr. H. W. Spangler, it will be found that the cylinders were each 14 ins. diameter by 25 ins. stroke; the engine developed on an average 127 I.HP. and 92.5 brake HP. at 160 revolutions per minute. The clearance space was practically 28% of the whole volume of the cylinder, that is, 28% of the volume swept by the piston plus the compression space. The theoretical efficiency of such an engine is 0.41, but the actual efficiency was found to be 0.277, so that

$$\frac{0.277}{0.41} = 0.675.$$

The actual efficiency, instead of being only 0.58 of the theoretical, rises to 0.675 of the latter, due to changes in the dimensions of the engine without practical change in the compression. The engine mentioned on page 11 as of 7 ins. diameter by 15 ins. stroke, gave an efficiency of 0.25, while the larger engine of 11½ ins. diameter and 21 ins. stroke, having a similar compression space, gave an efficiency of 0.275.

The theoretical efficiency in both cases is 0.428, and the ratios are

$$\frac{0.25}{0.428} = 0.58 \text{ and } \frac{0.275}{0.428} = 0.643.$$

The actual efficiency therefore increases with the dimensions of the engine, the compression remaining constant, as shown in the following Table:

Table Showing Comparison of the Actual and Theoretical Efficiencies of Otto Engines of Different Dimensions.

Engine Cylinder. Diam. ins.	Stroke. ins.	Relative capacity.	Theoretical capacity	Actual indicated Efficiency.	Ratio of actual and ideal efficiency.
7	15	1.00	0.428	0.250	$\frac{0.25}{0.428} = 0.58$
11½	21	3.77	0.428	0.275	$\frac{0.275}{0.428} = 0.64$
9½	18	1.00	0.40	0.210	$\frac{0.21}{0.41} = 0.53$
14	25	2.97	0.41	0.277	$\frac{0.277}{0.41} = 0.67$

There is, however, a limit to this increase of efficiency with increased dimensions. The increase in the efficiency of the larger engines as compared with the smaller using the same ratio of compression space is due to the diminished relative loss of heat from the gases produced by the explosion to the enclosing metal walls; and it is always found that in larger engines the expansion curve tends to rise more and more above the adiabatic line. With a maximum temperature of explosion of about 2,912° F., it is found by experiment that the actual increase of temperature due to explosion accounts for about from 0.6 to 0.7 of the total heat of the gas present. There is consequently heat enough present in a gas-engine of ordinary proportions, if none be lost, to maintain the temperature during expansion whilst performing work to the maximum 2,912° F. during the whole expansion stroke. This increase in dimensions, if carried to an extreme, could therefore only reduce the loss to insignificant relative proportions; and in such a case the mass of incandescent gas might be considered to lose no heat whatever to the walls of the cylinder.

Consider an air-engine in such a case; the total volume of the stroke plus clearance space being 1 cu. ft. Assume the engine to have a compression of space of 0.275 of the entire volume of the cylinder, then the diagram and results would be as shown in Fig. 51, when the temperature of explosion is 2,912° F.

From this it will be seen that while 0.409 is the efficiency for adiabatic expansion, 0.346 is the efficiency for isothermal expansion. Hence, it appears that, allowing for the known property of the suppression of heat in a

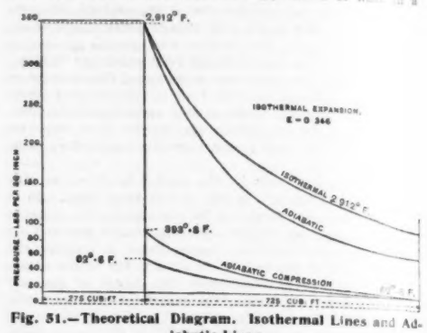


Fig. 51.—Theoretical Diagram. Isothermal Lines and Adiabatic Lines.

Efficiency of adiabatic compression and expansion = 0.409.
Work of adiabatic compression .... .. 3,414 foot-lbs.
Heat added for explosion .....24,622 "
Work of isothermal expansion at 2,912° F.18,264 "
Total heat added during cycle.....42,888 "

gaseous explosion, the utmost efficiency possible for an engine using coal-gas, having a compression space 27½% of the total volume of the cylinder, and expanding to the same volume as existed before compression, is 0.346. So the efficiency actually attained in practice is $\frac{0.277}{0.346}$ i. e., 80% of the possible value.

So far practice has shown that the absolute efficiency of the gas-engine has been increased from 16% in 1882 to practically 28% in 1895, and this great change in economy has been brought about by increase in compression alone. The pressure of compression has risen from 35 lbs. per sq. in. to 90 lbs. per sq. in. above atmospheric pressure.

The question arises, how far can this compression be still enhanced? It will be observed from the formulas i. and ii. that the efficiency increases somewhat slowly at the higher pressures; and thus a limit must be reached beyond which the increasing weight and dimensions of the parts of the engine due to rising maximum pressure will more than counterbalance the improved theoretical economy.

Assume, for example, that a compression of 210 lbs. per sq. in. above that of the atmosphere is feasible; the volume of the compression space will then be 0.144 of the total volume of the cylinder, so that the theoretical efficiency of such an engine will be.

$$E = 1 - \left(\frac{1}{6.95}\right)^{0.408} = 0.546.$$

The ideal efficiencies for different compressions thus stand—

E = 0.33 for 38 lbs. per sq. in. compression by gage.
E = 0.40 for 66.6 " "
E = 0.428 for 87.5 " "
E = 0.546 for 210 " "

Such a compression as 210 lbs. per sq. in. would produce, with an explosion temperature of 2,912° F., a maximum pressure of 675 lbs. per sq. in. above atmospheric pressure; and this would involve an engine having working parts nearly double the weight of those of the engine tested ,by the Author at Messrs. Crossley's, with but a moderate increase in power for the great increase in weight. The Author accordingly considers a compression of 200 lbs. per sq. in. as considerably above the limit likely to be useful in an "Otto" gas-engine.

The gas-engine is now rapidly nearing the limit of advantageous compression, so that no considerable further economy is to be expected there. In the diagram, Fig. 2, however, it may be observed that, at the moment of opening the exhaust-valve, there is still in the cylinder a pressure of about 50 lbs. per sq. in. above atmospheric pressure. It is obvious if the cylinder of that engine had been longer, and the piston could travel farther, that the pressure could have been reduced while the expanding gases were performing work on it. This source of economy has long been obvious, and many engineers have attempted to realize it in practice. The Author has calculated an ideal case of this kind in which the pressure of compression was 100 lbs per sq. in. above that of the atmosphere, the explosion temperature 2,912° F., and the adiabatic expansion carried on far enough for the contents of the cylinder to fall to atmospheric pressure. The theoretical efficiency of such an engine would be 0.73, and, with an engine of about 200 I.HP., a practical efficiency of 0.73 by 0.6 = 0.438 is probable. Efficiencies of 45% of the whole heat given to the engine are now within reach.

The question, however, as to whether greater or less expansion should be utilized in an engine is altogether a matter of dimensions. For small engines, great expansion, beyond the volume of the charge before compression,

[1] Trials of Engines for Electric Lighting. Journal of the Society of Arts, vol. xxxvii. p. 213.

is inadvisable; as the reduction of the volume of mixture dealt with at each stroke may easily so far increase the relative loss of heat to the cylinder, as to more than neutralize the gain obtained from the extra expansion. In very large gas-engines it will be undoubtedly advisable to adopt the compound principle, and many engineers have attempted it. So far, however, compounding has not proved successful. The principles involved are not yet thoroughly understood, and require further investigation.

Since 1876, when the largest gas-engine in Great Britain was of the old "Otto" & "Langden" type of 3 HP., gas engines have increased in size to 400 HP., and from an efficiency of 12% to 28%. The gas-engine will assuredly be yet applied upon railways and to ships, just as it is now being applied in factories; its principles are understood better than they were ever previously, and engineers are daily improving their knowledge of the properties of flame and the means of harnessing flame, instead of steam, to the great work of the world.

Abstract of Discussion.

Capt. H. Riall Sankey showed how advantageously the question of efficiency could be dealt with by means of the $\theta\ \varphi$ (theta-phi, temperature-entropy) diagram, which had been planned for steam by Mr. MacFarlane Gray. He could not help thinking that there was an arithmetical slip in the author's figure, 0.73; if so, the absolute thermal efficiency of 0.44 for an actual engine was not yet within reach. He had worked out the $\theta\ \varphi$ diagram of the ideal gas engine expanding to atmosphere which gave 73% absolute thermal efficiency and found that a compression of 90 atmospheres was needed. He stated that the thermal efficiency obtained by the usual formula implied working on the Carnot cycle, and required all the heat to be supplied at the higher and rejected at the lower temperature. The Carnot cycle was an impossible ideal for the gas engine, and for this reason it was, in his opinion, a mistake to take it as a standard of comparison.

Prof. W. C. Unwin referred to the statement of Mr. Clerk that Dr. Slaby and Prof. Thurston had erroneously calculated the heating value of the gases used by deducting the heat of the evaporation of water produced by the combustion. Whatever they had done, they had certainly not made an error, an oversight or a blunder. Questions as to the standard of efficiency were not questions of right or wrong but merely questions of definition and convenience as to which definition should be adopted. In the case of a gas engine, that heat which in the calorimeter resulted from condensing steam did not appear as heat in the action of the engine at all. The steam passed away into the chimney and it was one of the necessary losses of any gas engine which had not a condenser. He thought there was reason to do in the present case what was done in every boiler trial—to exclude the heat of evaporation of water produced as heat which did not appear in the action of the machine considered. No doubt rightly from his own point of view the author had adopted another definition and proceeded in another way. The one enormous loss in a gas engine was the cylinder-wall action, a loss amounting often to half the total heat produced, directly transmitted through the wall of the cylinder into the jacket. If that loss could be successfully attacked it would result in very large economy.

It was known, in the case of air compressors, that the effect of a water spray in a cylinder was enormously more rapid and more effective than the action of a cold water jacket. It was at least quite possible (he would not say that it would absolutely succeed, because experimenters with gas engines knew that difficulties often arose that had not been foreseen) to have a gas engine without a water-jacket and with a six-stroke cycle working in this way. There would be first the explosion stroke and exhaust stroke as in the ordinary cycle. Then a small amount of water would be sprayed into the cylinder, which would be evaporated by the hot cylinder walls. That would give a steam stroke is which some work would be developed at the expense of heat ordinarily rejected into the jacket. In the return stroke the steam would be discharged, and, lastly, there would be the ordinary suction and compression-stroke. About 1-5 oz. of water per stroke would carry off all the heat generated in the cylinder of a 10-HP. engine if evaporated.

Mr. Bryan Donkin said it would be interesting to test the question of the long exhaust-pipe, by experimenting on two gas engines of the same cylinder dimensions, running at the same speed, using the same gas, working with the same compression pressure and initial pressure, but one having a long exhaust pipe, and the other an exhaust pipe of ordinary length. It was evidently the author's opinion that the scavenging arrangements of Mr. Atkinson only increased the efficiency about 5%; but the expulsion of the products of combustion was a matter of importance. In modern gas engines the clearance-space was gradually diminished year by year, and particularly the clearance areas. He quite agreed with the author that the extent of the latter should be very carefully considered, as it was in steam engines.

Mr. W. Worby Beaumont said that the author had referred to the question of the rapid conversion of the heat of the explosion into mechanical work by reason of the small space through which the piston moved when doing a large part of the total work. It was not, however, an advantage that the piston should move slowly at the time of the combustion and conversion. It would be better if the piston could move through a greater space at this period, and it ought to be mentioned that some recent experiments with very high speed engines had shown that more work was obtained from a given quantity of gas by increasing the speed of the engine. This showed that a greater amount of the heat of the explosion was converted into mechanical work when that conversion took place at a high speed, a fact which suggested another line of thought for the modification of the gas engine in the future, besides that suggested by the author in referring to the new type of engine that he had recently designed. He was glad to observe that the author was not satisfied to consider the Otto cycle the ultimate standard, and that he had given good reason for changing his engine, and to a certain extent returning to the type that he devised some years ago.

Mr. Bertram Chatterton described a combined gas and steam engine, on which he had worked for about 2½ years and then abandoned it. He alternated a gas stroke and a steam stroke in the same cylinder, using no jacket. The cylinder was maintained at a uniform temperature of about 375° F., by priming water into the steam. The best results obtained were about 14 lbs. of steam and 11 cu. ft. of gas conjointly per I. HP., and about 18 lbs. of steam and 14 cu. ft. of gas conjointly per B. HP. The mean pressure of steam was 30.4 lbs. per sq. in. and the mean pressure of the gas 28.4 lbs. per sq. in. He thought a gas engine could be made on the constant pressure principle which involved certain advantages not alluded to by the author, and the difficulties mentioned by the author could be entirely overcome.

Mr. J. E. Dowson said that he was surprised to find that the author could not credit more that 5% gain in economy to the scavenging of the exhaust gases. He had made an experiment which showed a saving when scavenging of nearly 14%.

Prof. T. Hudson Beare said he was afraid unless engineers fully recognized that the figures given by the author were gas-consumption when the engines were working at full power they would be led into serious mistakes as to the cost of the power. In order to bring out the point, he had made eight or nine trials with a small Crossley tube-ignition engine of 4 N. HP., and three or four years old, measuring the B. HP. and gas-consumption, and the results were shown in Fig. 62. The load varied between zero and 7 HP., and the amount of gas per B. HP.-hour was shown. It was very large at a low power, and decreased considerably at a higher power. The actual figures were 22.3 cu. ft. per HP.-hour at full power, and 58.6 cu. ft. at about 1 HP. The speed and all other conditions were kept fairly constant during the trials. The other curve showed the total gas consumed per hour, and it would be noticed that the relation was expressed by a straight line, the well-known Willans law which applied to gas engines as well as steam engines. If users obtained their gas-consumption running light and at full power, they could at once obtain the gas consumption at any intermediate power. Most of the gas engines were only occasionally run to full power, and it was well, therefore, to remember that they were not getting their power quite as economically as would appear from the efficiency given for the full-power trials. As to mechanical efficiency, the author had said that the "best gas engines were now both from the mechanical and the heat-engine standpoint highly efficient machines." He had plotted out the mechanical efficiency for all records given in the Paper, and many others, and he found a surprisingly close agreement between all gas engines of the Crossley type. If efficiencies were plotted to a base of indicated power, it would be found that they would lie in almost an absolutely straight line, inclined to such an angle to the base that the average efficiency was 85%. Now, 85% of mechanical efficiency for a small engine was not very good. When in engines developing 100 HP., 15 HP. were spent to drive the engine that was not a good figure. It was even worse in some gas engines. For instance, a "Simplex" gas engine tested by Prof. Witz, showed that the I. HP. was 110, and the B. HP. 75, the mechanical efficiency in that case falling a little under 70%, so that with 110 HP. they were using 35 HP. to drive the engine.

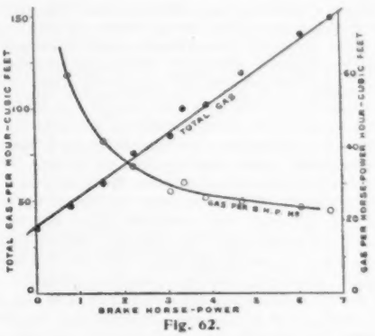


Fig. 62.

Mr. James Atkinson could not agree with the author in his estimate that only 5% of the increased economy was due to scavenging. He thought that the particulars given in the author's Paper were sufficient to show a much higher economy.

Very careful experiments had been made at Openshaw to ascertain the direct advantage of scavenging, and it was found that the shape of the combustion chamber, and many other conditions, had a considerable effect upon the results. In one instance a 14-HP. engine had been tested, all conditions being kept exactly constant, excepting that in one set of tests scavenging was used and the other it was not. The compression in both instances was 80 lbs. per sq. in. The non-scavenging engine developed 36.53 B. HP. with 20.30 cu. ft. per B. HP., while the scavenging engine gave 39.91 B. HP., with 16,489 cu. ft. per B. HP. There was another point in connection with the passing of cold air through the end of the cylinder, namely, that for every 5½° F., the charge of the cylinder was reduced in temperature before commencing to compress it, 1% more power could be obtained from the engine. No doubt the advantages of scavenging were partly due to the greater density of the charge.

Mr. F. W. Burstall wished only to criticise the cycle which the author had adopted as his standard for the Crossley engine. The particular expression he deduced was only true provided the specific heat of the air was constant for all temperatures. Mr. Le Chatelier had drawn up a table showing that the specific heat increased considerably with the temperature. The specific heat of a permanent gas increased from 1.0 to 1.3, between 0° C. and 1,000° C., taking the specific heat at 0° C. as 1.0, and that of carbon dioxide, which was one of the constituents of the exhaust product, increased from 1.0 to 1.6. These conclusions rendered all deductions in temperature in working out the diagrams of gas engine calculations open at least to doubt.

Prof. William Robinson said that in 1862, Mr. Beau de Rochas had clearly given the chief conditions essential to efficiency, and pointed out the advantages of compression, small cooling surface and high piston speed in the four-stroke cycle of operations which he proposed to be followed in the gas engine cylinder. The Beau de Rochas cycle was used 14 years afterwards by Otto, who made

his engine a success. Nevertheless to Mr. Beau de Rochas was due the credit of laying down the sound basis of gas-engine theory, and his cycle should not be called the "Otto cycle" by the author in the historical table. The scavenging arrangement of Messrs. Crossley and Atkinson relied upon the exhaust pipe, about 65 ft. long. It was not always convenient to lay such a great length of pipe, and the action must vary considerably with the number of bends, and the power at which the engine was working. Under varying conditions he feared the long pipe would not be found satisfactory. He was, therefore, inclined to advocate the claims of a positive scavenger such as in the Premier gas engine made by Messrs. Wells Brothers, of Sandiacre, near Nottingham. In this engine a certain amount of fresh air was pumped through the cylinder, and effectually cooled the space above the valves. Better results could be obtained in this way and with certainty. In the "Premier" tandum engine of 100-HP., the air-pump piston was 1.8 times the area of the motor piston, and the power absorbed by the scavenging was only 1%, much less than the loss due to back pressure in the Atkinson long-pipe arrangement.

Mr. Clerk, in closing the discussion, said that he had re-calculated the value of 0.73, stated by Capt. Sankey to be incorrect, and had obtained the same results. With regard to the use of the Carnot cycle for gas engines, it was the ultimate cycle which must be appealed to in deciding the absolute amount of heat which could be converted into work by any conceivable heat-engine. No engineer had ever thought it possible to follow Carnot and make an engine using the Carnot cycle in its entirety; but any gas engine cycle or even steam engine cycle, was after all simply a mutilated Carnot cycle, by mutilating which in a certain way any cycle for any type of gas engine could be produced. The Carnot cycle must always be appealed to, as Professor Beare has said, as showing the ultimate, not the possible efficiency, but the ultimate ideal efficiency, or the ultimate efficiency which was ideally possible. A gas engine cycle differed from a steam engine cycle in that, instead of having the temperature of steam in the boiler as the maximum limit, the temperature of the fuel in the furnace, that was to say, the gas mixture within the cylinder had the same relationship to the engine as the fuel in the steam engine furnace, therefore, a very much longer range, which made it difficult to compare the relative efficiency of these two engines; the only practicable method was to take the total number of heat units given to the two engines, calculate the ratio that represented the Carnot scale, or any other scale, and then compare the two, which would give the absolute standard. In all the experiments and calculations of Dr. Slaby, Professor Thurston, and Dr. Kennedy, they adopted an arbitrary method of determining the heat of combustion of the gas, which was that, instead of taking the total heat evolved from atmospheric temperature back to atmospheric temperature, which was the real heat evolved by the combustion, whatever it came from, they took only that evolved down to 100° C., and that retained all the water in a state of vapor, and also heated the gaseous fluid to a certain extent. He did not think that was correct. It was quite right to do that and so obtain a figure which gave a certain efficiency for the purpose of study, but he thought an absolute efficiency should be agreed upon, and that that should be on the lines he had indicated; and in determining that absolute efficiency, the whole generated, whether by condensed water or not, should be taken. With this heat of liquefied steam, it was quite possible, in some conceivable form of engine to obtain power; the function of the gas engine then began where that of the steam engine ended, and he thought it would be incorrect and misleading if the standard of cumbustion value which included all the heat evolved and not only a part of it was not used.

In stating that only 5% was to be credited to scavenging, what he meant was that only 5% was to be credited in engines operated by coal-gas. In using Dowson gas, where the gas-mixture was so weak that it was on the verge of missing ignition, a very small change in the relative amounts of the gas in an engine would make a large change in economy. In Dowson gas much more than 5% of benefit was obtained with scavenging, but with coal gas that was not the case. The gas consumption figures in Mr. Atkinson's various results without scavenging were higher than they ought to have been with Openshaw gas, for the powers of the engines tested.

He agreed with Mr. Bryan Donkin as to the importance of analyzing the products of combustion from a gas-engine cylinder, and the necessity of making this analysis in all careful tests. His experience, however, showed that in properly constructed modern gas engines the combustion of the gases was practically complete. In large engines, no doubt, at the moment the exhaust valve was opened the flame still existed in the cylinder, and combustion was still proceeding. This defect could only be remedied by increased expansion or by some arrangement such as a compound engine which gave more time for combustion. Without doubt the thermal efficiency of the large engine was superior to that of the small engine.

It was truly remarked by Mr. Beaumont that increased speed of piston opened a method for increased economy not mentioned in the paper. Further economies were to be gained by increased piston speed, but it was to be borne in mind that the economy of an engine of given valve dimensions might thereby be easily diminished. The port and valve areas in a high-speed engine required to be carefully designed to allow the cylinder to fill completely at the end of the stroke, and to allow the exhaust to discharge completely on the exhausting stroke. The ignition also had to be carefully arranged for high speed. He agreed with Professor Hudson Beare's remarks, but he hardly thought it necessary to warn engineers that the consumption rate given by an engine in ordinary work at less than maximum power were greater than the consumptions mentioned in the paper. This fact was well known to all engineers dealing with either gas or steam engines. Referring to the remarks of Mr. Burstall assuming the change of specific heat of air to be as stated by Messrs. Berthollet and Mallard and Le Chatelier (with which he did not agree) the air cycles and the formulas used in the Paper would not be affected. The standard would be as valuable whether the specific heat of air changed or not.

He agreed with Professor Robinson's remark as to certain advantages to be gained by a positive scavenger, such as was used in the Premier gas engine. Such positive scavenging he had long advocated, and, indeed, applied to an impulse-every-revolution engine as early as 1881. The question of the proper standard of heat value was not one of favorable consideration or otherwise to the gas engine, but was one of a correct standard from an absolute heat engine point of view, and on this point he considered the only true method of regarding the question was the one adopted by himself.

TELEPHONING TO A SUBMARINE DIVER is a recent electrical achievement. The experiment was tried at the wharf of the Chapman Wrecking Co., in New York city, on April 1, by Mr. H. T. Atkinson, engineer of the New York Telephone and Telegraph Construction Co., and Capt. C. P. Everett, who was the diver. In the diver's helmet were placed a small battery of six cells, a transmitter and a receiver, the latter being adjusted to his ear. When the diver was in 40 ft. depth of water conversation could be carried on between him and people on the shore with great distinctness.

A MEMORIAL MONUMENT to the late Col. F. K. Hain, for many years Vice-President and General Manager of the Manhattan Elevated Railway Co., of New York city, will be dedicated at his grave in Danville, Pa., May 26. It is expected that from 150 to 200 of the employees of the road, representing all the departments, will attend the ceremony. The money for the monument has been raised by voluntary subscriptions by the employees of the Manhattan Ry.

A PLEASANT INTERCHANGE OF COURTESIES recently took place between Mr. James Forrest, Honorary Secretary of the Institution of Civil Engineers of Great Britain, and the American engineers who formed the European excursion party in 1889, whose handsome reception and entertainment in England were due chiefly to Mr. Forrest's efforts. The members of the excursion party, in the latter part of last year, joined in the purchase of a handsomely framed artist proof steel engraving of "The Iron Worker in King Solomon's Temple," as a Christmas present for Mr. Forrest, and together with it their personal cards and greetings enclosed in a silver made by Tiffany & Co., of New York City. The work of the box was a fine sample of etched and enameled work, including the flags of the two nations in their proper colors and the inscription "Christmas Greetings to James Forrest, Secretary to the Institution of Civil Engineers, From American Friends. Xmas, 1896. One Root, Two Branches, One Tongue, Two Flags." Mr. Forrest received the present and the greeting on Christmas Day, and replied in a characteristic letter, abounding in expressions of good-will, lithographed copies of which have been sent to all the contributors to the present. In it Mr. Forrest gives expression to the following sentiment, which will be appreciated by the engineers of both countries:

> The emblem inscribed on the beautiful casket which contained the letters and cards conveys in a few words what should ever be uppermost in the minds of all true citizens on both sides of the Atlantic—how best to promote and to cement good-fellowship between the two English speaking nations. Engineers may claim to have taken advantage of their many opportunities to advance this desirable end. To the ladies, especially, my thanks are due for so graciously linking themselves in the bond which unites the engineering fraternity.

Mr. Forrest retired from active service as Secretary to the Institution, which position he had held for many years, just rest retired from active service as Secretary to the Institution, which position he had held for many years, just about the time when he received the present from his transatlantic friends, and was appointed Honorary Secretary in recognition of his long and valued labors on behalf of the Institution.

AN ARMOR PLANT AT NEWPORT NEWS, VA., according to rumor, is being discussed between Mr. C. P. Huntington and the Armstrongs, of England. It is reported that the proposition comes from the English makers of armor and ordnance, but nothing has as yet been definitely decided.

A COMPARISON OF THE NEW OCEAN LINERS, being built for the White Star and the North German Lloyd Companies, with the "Great Eastern," is made by "The Engineer," of London, as follows:

	No. Ger. Lloyd's steamers.	White Star "Oceanic."	"Great Eastern."
Length bet. perpendiculars, ft...	625	680	680
Length over all, ft.	645	704	697
Beam, ft.	66	72(?)	83
Draft, ft.	26	26	28
Molded depth, ft.	43	...	...
Displacement, tons 20,500		24,349(?)	32,160
Gross tonnage, tons 13,700		17,000	22,000
Indicated horse-power 30,000		45,000	2,700
Speed, knots	23	27	12
Number of propellers	2	3	*1
Est. coefficient of fineness.....	.67	.67(?)	.71

*And paddle-wheels.

From the above it will be seen that the old 'Great Eastern" has yet to be beaten in displacement, or actual size. The greatest contrast is in the indicated horse-power of the engines and the resultant speed.

THE TORPEDO BOATS authorized by the last Congress and for which $800,000 was appropriated are to be 30-knot vessels of about 240 tons each, ready for their trial trip, and 270 tons with all service weights aboard. Secretary of the Navy Long has decided that the appropriation is exclusive of armament, and he hopes to thus secure boats larger than were originally proposed.

NEW PIERS 48 and 49, on the North River front of New York city, were bid for by the White Star Line, at $84,350 and $82,610 respectively per annum. This offer was made on a basis of 4½% on the cost of construction represented by these piers. The application was practically denied by the Dock Board, as a rental of 5% was demanded.

EXCESSIVE DOCK RENTALS at New York are being discussed by the Dock Board and Sinking Fund Commission and the representatives of steamship lines. The contention is that prevailing rentals are too high and injure the commerce of this port. The purpose of the present meeting is to agree upon what would be "moderate" rentals for the large modern piers now decided upon and under construction.

A BELL TELEPHONE COMPANY LOSING MONEY is the remarkable fact in Canada, according to the statements made by its officers in a petition to the Governor-in-Council to allow it to advance its rates. The following figures are given for three cities:

	No. of sub-scribers.	Revenue per sub-scriber.	Expenditure per subscriber.	Profit.	Loss.
Montreal	6,012	$39.01	$34.13	$4.88	....
Ottawa	1,176	31.37	42.42	....	$11.05
Toronto	4,710	36.67	53.63	....	16.96

In Toronto the rate now is only $25 per year for residences and $45 for business establishments. The company asks that it be allowed to raise its rates to a paying basis, with a maximum rate of $75.